THE EFFECTS OF A NOVEL EXERCISE TRAINING SUIT ON CARDIORESPIRATORY FITNESS, BODY COMPOSITION AND LEG STRENGTH

A Thesis
presented to
the Faculty of California Polytechnic State University,
San Luis Obispo

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Kinesiology

by
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June 2015

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ABSTRACT

The Effects of a Novel Exercise Training Suit on Cardiorespiratory Fitness, Body Composition and Leg Strength

Trevor Michael Curry

The physiological responses to physical activity or exercise using external load carriage systems (LCS) in the form of weighted personal protective equipment, backpacks, or vests have biomechanical and human performance implications. It remains unclear whether a new unique LCS in the form of a weighted (5.45 kg) full-bodied exercise suit can induce greater improvements in performance and body composition. Twenty-one healthy males (20±3 years; 24.9±3.6 body mass index (BMI); 25.1±6.4% total percentage body fat (% fat); 120.1±17.3 kg lean mass; 146.2±35.4 kg leg press 1-repetition max; 1.25±0.14 $g \cdot cm^{-2}$ bone mineral density; 49.5±8.53 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ maximal oxygen consumption (VO_{2max})) were matched for VO_{2max} and physical characteristics before being randomly allocated into an aerobic exercise intervention with or without the exercise suit using a treadmill at the Cal Poly Recreation Center. Participants jogged at 60%-70% of their maximum heart rate for 30 min three times a week on nonconsecutive days for six weeks. Weight was recorded before and after each session while heart rates, blood pressures, and tympanic membrane temperatures were recorded incrementally during each session. Thereafter, VO_{2max} and the same physical characteristics were measured and used to analyze the changes before and after the 6-week program. The results indicate that there was no difference for the change in any of the variables measured during and between the exercise intervention. Future studies examining the effect of the exercise suit on these variables should strongly consider larger sample sizes and other subpopulations to gain the statistical power to measure the effects of the exercise suit.

Keywords: aerobic exercise, body composition, bone mineral density, load carriage system, maximal cardiorespiratory fitness, weighted exercise suit

ACKNOWLEDGMENTS

I would like to express my special appreciation for Lawrence Petrakis, M.D., Athlotek L.L.C. and thesis committee members Steve Davis, Ph.D., Aydin Nazmi, Ph.D., and Don Clegg, M.S. Thank you all for your encouragement, guidance, and resources that allowed me to grow as a student and researcher. To Dr. Petrakis and Athlotek, L.L.C., thank you for taking interest with STRIDE and selecting me to conduct research on a remarkable exercise suit. I have enjoyed all the exercise testing with the suit and hope that there will be continuing research on it. Thank you Dr. Davis for taking the thesis committee chair position and guiding me through this process. I appreciate all of your words of wisdom and suggestions that helped me make this research experience that much better. In addition, I wouldn’t have been able to manage my thesis without the help of Dr. Nazmi. Thank you for helping me stay accountable and meeting the thesis expectations in a timely manner. It was also a pleasure to work under you as the Program Coordinator of the Assessment Team (A-Team) for STRIDE. Special thanks for my students enrolled in A-Team during my data collection. I hope all of you gained insight to the research process. Professor Clegg, thank you for your support when I needed it the most. I appreciate that you were able to be a part of my thesis committee and help me finalize my thesis project. To my fellow Kinesiology graduate students James Aicardi and Haley Terndrup, thank you for helping me with all the exercise testing and data collection. I couldn’t have done it without you two. Last but not least, I want to thank my family. You all are the best support system and a joy to be around!

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

Table

LIST OF FIGURES

Chapter 1

Introduction

Background of the Study

Individuals engaged in academics, athletics, recreational activities, or certain occupations (e.g., military) often carry light to heavy loads using packs at different anatomical positions. Load carriage has been defined as locomotion while transporting an external mass supported on the upper torso by shoulder straps and/or hip belts (Knapik, Harman & Reynolds, 1996). Studies have explored the belief that training with loads of certain body weight percentages can improve performance (Faigenbaum, McFarland, Schwerdtman, Ratamess, Kang & Hoffman, 2006; Rusko & Bosco, 1987). Other studies have demonstrated that lung function and performance become impaired with heavy loads carried at various positions (Chow, Ting, Pope & Lai, 2009; Dominelli, Sheel & Foster, 2012). Military researchers demonstrated that physical conditioning increases from wearing protective equipment or carrying loads among infantry soldiers (Swain, Onate, Ringleb, Naik & DeMaio, 2010). However, exaggerated physiological responses due to hot and humid environments were reported in soldiers wearing body armor (Majumdar, Srivastava, Purkayastha, Pichan & Selvamurthy, 1997). Based on these findings, load carrying apparel and clothing have been developed due to the implications they bring to human performance.

Backpacks, weighted vests, hand weights, and personal protective equipment or a combination thereof have been conventional forms of load carriage. These modes have been investigated, primarily at the body's center of gravity on the torso, at 10%-50% of body weight. New load carrying innovations have been developed by Athlotek, L.L.C., a research and development company with a unique platform of customized processing technologies for engineering and developing innovative polymer products (Hayward, California). Athlotek pioneered a novel approach of creating a field of uniformly-distributed weights over a person's whole body in the form of a thin and flexible fabric. The fabric, known as Athlotex^{TM}, has a uniform weight distribution of a proprietary weight/cm^2, it combines biaxial stretching, breathability and aesthetic appearance for its tailoring into exercise garments with different weights. The Athlotex^{TM} fabric is a laminate composite of Spandex with other synthetic and natural fibers and a thermoplastic polyurethane in which uniformly distributed weights, in the form of small stainless steel beads, are an integral part of the fabric.

Research examining the physiological effects of a uniformly-weighted exercise suit that covers the body similar to a jacket and pants is limited. Most research investigating load training through weighted vests or backpacks confirms that, in most cases, cardiorespiratory and strength measures increase among healthy, trained individuals (Knapik et al.,1996; Liu, 2007; Swain et al., 2010). Improvements in aerobic capacity were achieved through endurance training, which induces cardiovascular, respiratory and biochemical modifications. Training with weighted vests or suits also stimulated advances in human performance and strength. This stemmed from skeletal muscle fiber conversion (slow to fast twitch), which resulted in muscle hypertrophy (Bosco, Zanon, Rusko, Dal Monte, Bellotti, Latteri & Bonomi, 1984). Training with extra loads through weighted vests or suits has health benefits. It increases cardiorespiratory fitness, as estimated by VO_{2max}, which is inversely related to coronary heart disease and all-cause mortality (Blair, Kohl, Paffenbarger, Clark, Cooper &

Gibbons, 1989). The relative proportion of muscle mass is greater compared to fat mass. Excessive fat is an established risk factor for cardiovascular disease (CVD) and increases all-cause mortality (Atkins, Whincup, Morris, Lennon, Papacosta & Wannamethee, 2014). The nature in which load training brings health improvement is significant, however, previous research used obtrusive weight-bearing techniques for load training. It has been hypothesized that a convenient, more applicable mode for load training can be performed through a well-fitted uniformly-weighted suit. The practicality of this method will allow users to benefit from load training with greater ease compared to carrying weighted objects, weighted vests, or even heavy body armor. Collectively, this may address a large public health epidemic, obesity.

Each year, 28 million individuals are dying from the consequences of overweight or obesity worldwide. High body mass index (BMI) is associated with the development of cardiovascular risk factors such as hypertension, dyslipidemia, insulin resistance, and diabetes mellitus leading to cardiovascular diseases, such as coronary heart disease and ischemic stroke (Bastien, Poirier, Lemieux & Després, 2014). In a recent attempt to capture the obesity prevalence in the United States, Ogden, Carroll, Kit and Flegal (2014) used the National Health and Nutrition Examination Survey (2011-2012) where obesity was defined as BMI greater than or equal to 30 for adults aged 20 years and older. They found that in 2011-2012, the prevalence of obesity in adults was 34.9%. This staggering statistic has been the focus for many public health practitioners because of the economic burden it brings to healthcare and long-term health consequences it has for the individual.

Sedentary behaviors appeared to be large contributors to the development of obesity. In 1992, the American Heart Association (AHA) named physical inactivity as an independent risk factor for CVD (Dunn, Marcus, Kampert, Garcia, Kohl & Blair, 1999). Several organizations addressed this issue and delineated recommendations for physical activity in order to call attention to health-related benefits from physical activity. The American College of Sports Medicine (ACSM) and Centers for Disease Control and Prevention (CDC) published national guidelines on physical activity and public health. The Committee on Exercise and Cardiac Rehabilitation of the American Heart Association endorsed and supported these recommendations. They stated, "To promote and maintain health, all healthy adults aged 18 to 65 years need moderate-intensity aerobic (endurance) physical activity for a minimum of 30 minutes on five days each week or vigorous-intensity aerobic physical activity for a minimum of 20 minutes on three days each week. Combinations of moderate- and vigorous-intensity activity can be performed to meet this recommendation" (Haskell, Lee, Pate, Powell, Blair, Franklin, Macera, Heath, Thompson & Bauman, 2007).

> The "2008 Physical Activity Guidelines for Americans Summary" from the Office of Disease Prevention and Health Promotion stated key guidelines for adults: All adults should avoid inactivity. Some physical activity is better than none, and adults who participate in any amount of physical activity gain some health benefits. For substantial health benefits, adults should do at least 150 minutes a week of moderate-intensity, or 75 minutes a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous intensity aerobic activity. Aerobic activity should be performed in episodes of at least 10 minutes, and preferably, it should be spread throughout the week (U.S. Department Health and Human Services, 2008).

Ogden et al. (2014) indicated that there were no significant changes in adult obesity prevalence between 2003-2004 and 2011-2012. Clearly, more adults should increase physical activity and decrease sedentary behaviors in order to obtain the related health benefits. Moreover, several companies have developed and disseminated exercise apparel intended to facilitate the results from exercise much faster compared to traditional exercise with no special weighted or non-weighted apparel. Despite the large diversity of exercise apparel, little research has examined how efficacious it is for reducing body fat.

Statement of the Problem

Most of the research investigating weighted personal protective equipment or load carriage systems using backpacks or vests has been centered on the biomechanical constraints or the effects of the system on the mechanical efficiency of human performance. Very limited research has investigated the effects of a full-bodied, moderately-weighted and uniformly-distributed exercise suit as an exercise training modality for improving human performance.

Statement of the Purpose

The purpose of this study was to investigate the effects of wearing a uniformly-weighted exercise training suit on maximal oxygen consumption (VO_{2max}) blood pressure, heart rate, ratings of perceived exertion, tympanic membrane temperature, body composition and leg strength during a 6-week aerobic exercise intervention among sedentary individuals.

Delimitations

The study was delimited to the following parameters:

1. Only 25 sedentary, male participants between 165 cm and 188 cm with BMI's between 18-30 who able to exercise 3 times per week, approximately 40-minutes at a time, for 6-weeks, were recruited as subjects.

2. All tests were performed at the Webb Human Performance Laboratory of Cal Poly, San Luis Obispo, between January, 2014, and March, 2014.

3. Maximal cardiorespiratory fitness was determined from indirect calorimetry using the Bruce Protocol (Kaminsky & Whaley, 1998) on a treadmill.

4. Heart rates were determined from digital telemetry using a Polar^{TM} heart rate monitor and watch.

5. Blood pressures were determined from sphygmomanometry.

6. Core temperatures were estimated from tympanic membrane temperatures using the BRAUN ThermoScan 5 ear thermometer.

7. Body composition and bone mineral density were determined using Dual X-ray Absorptiometry (DXA).

8. Leg strength was determined from the ACSM 1-repetition maximal leg press protocol using a Life Fitness leg press machine within the Cal Poly Recreation Center.

9. All exercise sessions were performed in the Webb Human Performance Laboratory and Recreation Center of Cal Poly, San Luis Obispo between January, 2014, and March, 2014.

10. All participants were instructed to continue their normal daily routines, which included physical activity and nutritional intake.

Assumptions

The study was based on the following assumptions:

1. It was assumed that all participants adhered to all protocols used in this study (See Appendices).

2. It was assumed that all participants did not consume any supplements or medications that altered body composition, human performance, physiological or metabolic responses to human movement.

3. It was assumed that all participants gave a maximal effort during every exercise assessment.

4. It was assumed that all participants were well rested for every exercise test.

5. It was assumed that all participants wore the weighted, experimental exercise suit to manufacturer specifications.

6. It was assumed that all participants wore exercise appropriate clothing to all exercise sessions.

7. It was assumed that the assistant researchers followed every protocol used in this study.

Limitations

The study was limited by the following factors:

1. The nutritional behavior of participants was not controlled for.

2. The psychological state and motivation may have affected participant's performances.

3. The funding for this project was limited.

Research Hypotheses

1. Maximal oxygen uptake (VO_{2max}) testing with the uniformly-weighed exercise suit will result in greater oxygen consumption at any given submaximal work rates compared to testing without the suit.

2. Maximal oxygen uptake (VO_{2max}) testing with the uniformly-weighted exercise suit will result in greater respiratory exchange ratios at any given submaximal work rates compared to testing without the suit.

3. Maximal oxygen uptake (VO_{2max}) testing with the uniformly-weighted exercise suit will result in greater blood pressures (systolic and diastolic) at submaximal work rates compared to testing without the suit.

4. Maximal oxygen uptake (VO_{2max}) testing with the uniformly-weighted exercise suit will result in greater Ratings of Perceived Exertion compared to testing without the suit.

5. Maximal oxygen uptake (VO_{2max}) testing with the uniformly-weighted exercise suit will result in greater heart rates at any given submaximal work rates compared to testing without the suit.

6. Maximal oxygen uptake (VO_{2max}) testing with the uniformly-weighted exercise suit will result in greater tympanic membrane temperatures at any given submaximal work rates compared to testing without the suit.

7. Maximal oxygen uptake (VO_{2max}) testing with the uniformly-weighted exercise suit will result in faster times to exhaustion compared to testing without the suit.

8. Exercise training with a uniformly-weighted exercise suit will result in a greater improvement in VO_{2max} compared to a control.

9. Exercise training with a uniformly-weighted exercise suit will result in greater lean mass development compared to a control.

10. Exercise training with a uniformly-weighted exercise suit will result in greater percent fat mass loss compared to a control.

11. Exercise training with a uniformly-weighted exercise suit will result in greater total body percentage fat (% fat) loss compared to a control.

12. Exercise training with a uniformly-weighted exercise suit will result in greater weight loss compared to a control.

13. Exercise training with a uniformly-weighted exercise suit will result greater changes in bone mineral densities compared to a control.

14. Exercise training with a uniformly-weighted exercise suit will result in greater changes in leg strength compared to a control.

15. Exercise training with a uniformly-weighted exercise suit will result in longer times to exhaustion (i.e., greater endurance) compared to a control.

Definition of Terms

Aerobic exercise. Structured physical activity for which the ATP requirement may be met through aerobic metabolism without accumulation of lactic acid.

Anaerobic exercise. Structured physical activity for which the ATP requirement exceeds the amount available through aerobic metabolism.

Body Composition. The body's constituents, usually expressed using a two compartment model describing the proportion of lean mass to fat mass.

Body Mass Index (BMI). An index score given based upon an individual's height (m) and weight (kg), which is expressed as $kg{\cdot}m^{-2}$.

Bone Mineral Density. The amount of bone mineral matter per square centimeter, which is expressed as $g \cdot cm^{-2}$.

Cardiorespiratory Fitness. The ability of the body to sustain prolonged aerobic exercise.

Diastolic Blood Pressure (DBP). The lowest arterial pressure during a cardiac cycle, resulting from ventricular diastole.

Forced Expiratory Volume (FEV_1). The amount of air expelled from the lungs in one second during a maximal exhalation following a maximal inspiration, expressed in (L).

Forced Vital Capacity (FVC). The maximum volume expired by the lungs after maximum inspiration expressed in (L).

Fat Mass (FM). The absolute amount of body fat

Fat-free Mass (FFM). The mass of the body that is not fat, including muscle, bone, skin and organs. Also known as lean mass.

Heart Rate (HR). The number of heart beats per minute expressed as $beats \cdot min^{-1}$ (bpm)

Maximal Oxygen Consumption ($\dot{V}O_{2max}$). The maximal volume of oxygen utilized by the body per minute, expressed in $mlO_2 \cdot kg^{-1} \cdot min^{-1}$ or $LO_2 \cdot min^{-1}$, standard temperature and pressure, dry.

Oxygen Consumption ($\dot{V}O_2$). The volume of oxygen utilized by the body per minute, expressed in $mlO_2 \cdot kg^{-1} \cdot min^{-1}$ or $LO_2 \cdot min^{-1}$, standard temperature and pressure, dry.

Rating of Perceived exertion (RPE). A rating based upon Borg's rating of perceived exertion scale which quantifies the total level of exertion experienced by the subject in increasing intensity from 6 to 20 (Borg, 1982).

Respiratory Exchange Ratio (RER). The ratio of the volume of carbon dioxide produced to the volume of oxygen consumed.

Systolic Blood Pressure (SBP). The greatest arterial blood pressure during a cardiac cycle, resulting from systole.

Thermoregulation. The process by which the hypothalamus controls the body's temperature.

Time to Exhaustion. The total number of minutes spent running before the subject could no longer continue at the set workload.

Tympanic Membrane Temperature. The body core temperature as measured electronically at the tympanic membrane.

Ventilation (V_E). The volume of air exhaled expressed in $L \cdot min^{-1}$.

Chapter 2

Review of the Literature

This Review of the Literature was completed prior to data collection and thematically organized into seven sections in order to provide a foundation pertinent to this study. The initial sections are centered on external load positioning with various load carrying systems and their effects on human gait, energy costs and cardiorespiratory systems. The subsequent sections review literature that is more closely related to this study. These sections are concentrated on the acute physiological effects of load training with non-weighted or weighted exercise apparel among athletes and military equipment with soldiers. The last section will discuss exercise prescription for overweight and obese individuals.

Load Positioning and its Effect on Human Gait

Humans have long used a variety of external load carrying utilities or techniques to effectively transport objects. In order to compare walking mechanics between genders, Rohmert, Wangenheim, Mainzer and Zipp (1987), had men and women perform over-ground walking at 1.78 $m \cdot s^{-1}$ under five load conditions (0 kg, 9 kg, 17 kg, 29 kg, and 36 kg) using cinematography. The 2 heaviest loads were carried using a framed rucksack system. The results indicated that men and women had significantly different gait patterns under all load conditions. Women increased their step frequency as load increased due to shorter stride lengths. In addition, stride length and swing time decreased while stride rate increased with increases in load among both genders. There was also an increased forward inclination of the trunk only with the two heaviest loads for both genders. Men were not as affected by increases in load carriage compared to women. This might be due to the physiological and biomechanical differences between men and women.

Birrell and Haslam (2010) investigated the effect of different distributions of carried load on kinetic parameters of human gait using cinematography. The 3 military load carriage systems (LCS) were in Backpack, Standard and AirMesh or a combination thereof to carry 4 different loads (8 kg, 16 kg, 24 kg and 32 kg) over a force plate at 1.5 $m \cdot s^{-1}$. The researchers found that the Backpack LCS produced a lower force compared to the Standard LCS at all loads. Stance time was significantly lower in the Backpack LCS compared to the Standard LCS at 32 kg, with the trend to be lower at 24 kg. Maximum braking force was significantly reduced in the AirMesh LCS compared to the Backpack and Standard LCS when carrying 32 kg. No other significant differences were found. It was noted that changing the distribution of the load within the LCS had limited effect on the ground reaction force parameters of human gait. The authors concluded that double-pack backpacks, like the AirMesh used in this study, have significant benefits when considering the kinematics and energetics of load carriage because they are effective in reducing braking forces.

Load Positioning and its Effect on Energy Costs

Previous research has found that the energy cost of walking with a backpack increases progressively with increases in load and body mass, walking speed or surface grade. Abe, Yanagawa and Niihata (2004), investigated the effects of load, load position, and walking speed on the energy cost of walking. This study was based on the phenomenon of "free-ride," a change in biomechanical factors such as stride frequency and length when carrying loads at various positions on the body. To test this phenomenon, participants walked on a level terrained treadmill at step progressive, incremental step frequencies using a metronome. Additionally, participants walked with various loads which included a backpack at various weights (6 kg, 9 kg and 12 kg), weights on each ankle (1 kg, 1.5 kg and 3 kg), weights in each hand (1.5 kg, 3 kg and 4.5 kg) or no weights (control). Oxygen uptake ($\dot{V}O_2$) was measured in order to calculate the ratio of the steady state oxygen consumption above resting oxygen consumption to the walking speed (C_w).

For loads carried on the back, ankles and hands, all C_W values were greater at lower and faster walking speeds. For moderate walking speeds (70 $m \cdot min^{-1}$, 80 $m \cdot min^{-1}$ and 90 $m \cdot min^{-1}$) smaller C_w values were generated. Specifically, C_w values of 9 and 12 kg load conditions significantly decreased at slower speeds when the load was carried on the subject's back. This trend was observed until 80 $m \cdot min^{-1}$. The researchers discussed that load weight positively influenced C_w values, possibly due to increased rotative torque around the center of body mass at slower speeds. The researchers concluded that an energy saving phenomenom similar to "free-ride" was observed when a load was carried on the back at slower walking speeds.

Stuempfle, Drury and Wilson (2004) compared the physiological and perceptual responses to a load carried at a high, central, or low position in an internal frame backpack. Participants were tested on three separate occasions with a minimum of 24 hours between visits. Backpacks were loaded with 25% of the participant's body weight. The location of the load was randomly assigned so that the order of the load placement varied among participants for the three trials. After a 5 minute warm-up and moderate stretching, participants walked with the backpack at 2 mph and 0% grade for 1 minute followed by 9 min of walking at 3.2 mph and 0% grade for each backpack position. The results indicated that $\dot{V}O_2$, ventilation, and ratings of perceived exertion were significantly lower in the high position (18.6 ± 2.3 $mlO_2 \cdot kg^{-1} \cdot min^{-1}$, 31.7 ± 5.0 $L \cdot min^{-1}$ and 2.8 ± 0.8, respectively) compared to the low position (22.2 ± 3.0 $mlO_2 \cdot kg^{-1} \cdot min^{-1}$, 38.6 ± 7.5 $L \cdot min^{-1}$ and 3.7 ± 1.0, respectively). Heart rate and respiratory exchange ratios did not change significantly as the load was moved from the high to the low position. These results demonstrated that physiological and perceptual responses were affected by load placement. The researchers concluded that positioning heavy items high in the backpack might improve the ability of an individual to perform sustained load carriage. Load placement was also an important factor in the efficiency of load carriage, and should be considered in the design and loading of backpacks.

Lloyd and Cooke (2000) evaluated the energy cost of load carriage using both a traditional rucksack and a new load carriage system. The new system incorporated front balance pockets, allowing the load to be distributed between the back and front of the trunk. Participants walked on a treadmill at 3 $km \cdot hr^{-1}$ for 3 min stages at uphill and downhill gradients for a total of 15 minutes. Expired air was collected throughout both the downhill and uphill sections and used for data analysis. The oxygen consumption associated with both of the loading conditions was significantly ($P < 0.001$) higher than that associated with unloaded walking at all downhill gradients tested. However, there was no significant difference between the two loading conditions. Oxygen consumption associated with the new load carriage system was significantly ($P < 0.05$) lower than that associated with the traditional pack at the 0%, 5%, 10%, and 20% uphill gradients. The findings suggested that a load carriage system that allows the load to be distributed between the back and front of the trunk is more appropriate for carrying relatively heavy loads than a system that loads the back only.

Liu (2007) examined the physiological effects of backpack load position, walking speed, and surface grade in infantry soldiers who had completed basic training. Eight treadmill walking bouts at one of two speeds (3.2 $km \cdot h^{-1}$ and 6.4 $km \cdot h^{-1}$) and two surface grades (0% & 6%) carrying 15% of their body weight in a backpack with two chambers (upper and lower) were completed. Respiratory frequency, ventilation, $\dot{V}O_2$ and heart rate were recorded during each trial. The researchers found that walking on a 6% grade was associated with higher $\dot{V}O_2$ and heart rate compared to walking at 0% grade. Furthermore, there was a significant interaction between load position and walking grade on oxygen consumption. Here, the mean $\dot{V}O_2$ was significantly higher when loads were carried in the upper position and walking at 6% grade. The researchers suggested that the load's center of gravity should be placed as close to the body as possible to maximize breathing efficiency. However, the researchers affirmed that higher positioned loads could affect cardiorespiratory function.

Load Positioning and its Effect on Cardiorespiratory Systems

Chow, Ting, Pope and Lai (2009) assessed the effects of backpack load placement on pulmonary capacities of normal school children. The researchers hypothesized that the effects of a backpack on pulmonary function could be optimized by varying the backpack center of gravity. To test this, school children performed forced vital capacity (FVC), forced expiratory volume (FEV), peak expiratory flow (PEF), and forced expiratory flow (FEF) maneuvers during free standing and when carrying a backpack of 15% of body weight with its center of gravity positioned at the upper back, mid back, and lower back. The researchers found that the effect of loading condition was significant for both the absolute and referenced values of FVC and FEV ($P < 0.001$). However, no significant effect of load placements on the pulmonary function was found. These findings might have been due to the decrease in expansion ability of chest wall resulting from kyphotic posture during backpack carriage. The kyphotic position might have affected the mechanical efficiency of the pulmonary muscles and their power, which might have limited their ability to control the rib cage for respiration. It was concluded that pulmonary function may be more susceptible to backpack load than load placements.

Daneshmandi, Rahmani-Nia and Hosseini (2008) investigated the cardiorespiratory effects and compared the changes induced by carrying different weights of backpacks from rest to exercise (15 min walking) and 3 minutes after that (as the recovery) in adolescent students. A school backpack with two pads and wide straps on the shoulders and one at the hip was used for this study. Backpacks were filled with books and other educational material so that they weighed 0% (control), 8%, 10.5% and 13% of each individual subject's body mass. Physiological parameters studied included heart rates, blood pressures, minute ventilation, and respiratory frequency. The results indicated that systolic blood pressure and minute ventilation during and 3 minutes after carrying backpacks at 10.5% and 13% of body weight were significantly higher than 0% and 8% body weight load conditions. Diastolic blood pressure also increased significantly only at the 13% body weight load condition after 15 minutes of walking. Carrying backpacks at 8% body weight did not significantly change cardiorespiratory parameters. These results are consistent with those found in adults. The researchers proclaimed that carrying backpacks equal to 10.5% of body mass or more significantly increases the systolic blood pressure, diastolic blood pressure, and minute ventilation in adolescent students. The authors also noted that it is possible that the biomechanical changes associated with load carriage could affect cardiorespiratory function, which could limit exercise capacity.

Dominelli, Sheel and Foster (2012) determined the effects of three different weights of backpacks on resting pulmonary function and respiratory mechanics during treadmill walking. After 10 minutes of resting metabolic and ventilatory measurements, the subjects completed five, randomized exercise bouts for 2.5 minutes, twice, on a treadmill with: no backpack (NP), an un-weighted backpack (NW) or a backpack weighing 15 kg, 25 kg, or 35 kg. A maximal expiratory flow volume curve was generated for each backpack condition and an esophageal balloon catheter was used to estimate pleural pressure. The researchers found that the heaviest backpack was associated with the greatest reduction in resting FVC and FEV, with minimal changes in the FVC to FEV ratio and no change in expiratory flows. Furthermore, the power of breathing requirement did not differ between backpack conditions when comparing similar ventilation. End expiratory lung volume during the exercise bout declined as the backpack weight increased. Additionally, as backpack weight increased there was a concomitant decline in calculated maximal ventilation, a rise in minute ventilation, and a resultant greater utilization of maximal available ventilation. In conclusion, these findings suggested that exercising while wearing a heavy backpack changes the respiratory mechanics of the lungs and places additional metabolic stress on an individual.

Dominelli et al. (2012) discussed how exercise with load carriage increases the work and power of breathing through a curvilinear increase due to the physiological stress placed upon the cardiorespiratory system. The restrictive component of backpacks limits operational lung volumes and reduces the efficiency of the respiratory muscles as their length-tension relationship is altered. However, during load carriage, the thoracic volume is reduced and the external limit is placed upon the inspiratory reserve capacity, which shifts the operational lung volume to a lower fraction of total lung capacity, reducing efficiency and increasing the work of breathing (Dominelli et al., 2012)

Non-weighted or Weighted Exercise Apparel

Duffield and Portus (2007) compared the effects of three different types of full-body compression garments and a control condition on performance in intermittent, repeat-sprint and throwing performance in cricket players. During each session, measures of heart rate, skin temperature, change in body mass, rating of perceived exertion and perceived muscle soreness were recorded. Capillary blood samples were analyzed before and after exercise for lactate, pH, O_2 saturation and O_2 partial pressure, and 24 h after exercise for creatine kinase (CK). Ratings of perceived muscle soreness were also obtained 24 h after exercise. Ten physically fit, male, club-level cricket players were recruited and performed five testing sessions at the same time of day, separated by 72-96 hours in a temperature controlled biomechanics laboratory using a synthetic track.

Five testing sessions on the same day, including 1 familiarization trial, were completed by club-level cricket players which included throwing for distance, throwing for accuracy, repeat sprints for time, and shuttle runs for time. Each subject tested with three different compression garments and a control (no garment): a full-body Skins garment (Skins, Sydney, New South Wales, Australia); a full-body Under Armour (UA) garment (Under Armour, Baltimore, Maryland, USA); or a full-body Adidas garment (Adidas, Herzogenaurach, Germany).

No significant differences were seen for sprint, shuttle or throwing tests. In addition, no significant differences were seen in pre- and post-exercise heart rate, body mass, and rating of perceived exertion. Mean skin temperature was lower and significantly different in control compared to compression garments but not between compression garments during exercise. Creatine kinase concentration was significantly lower 24 hours after exercise in the Skins and UA conditions when compared with the control conditions. No significant differences were seen in other capillary blood measures. The authors concluded that compression garments did not improve sprint, shuttle, or throwing performance. There may be benefits in their use as a thermal insulator in cool conditions, and further as a recovery intervention utility after high-intensity exercise.

Rusko and Bosco (1987) stressed that added load increases heart rate and carbohydrate metabolism during submaximal exercise and increases the stress on the muscles. To examine this, cross country skiers and long-distance running endurance athletes with experience and year round training programs (7-10 training sessions each week) were divided into experimental and control groups following their training regime. The experimental group was instructed to wear a weighted vest (9%-10% of body weight) for four weeks every day from morning to evening. Furthermore, the experimental skiers wore the added load during every training session, and the experimental runners wore it for 3-5 training sessions each week. The examination consisted of two running tests (long and short) on a treadmill and a maximal running test up stairs.

After 4 weeks of training, the control group had a significantly lower blood lactate concentration when running at 10 and 14 km·hr^{-1} ($P < 0.001$) whereas the experimental group had significantly higher blood lactate and oxygen uptake ($P < 0.01 – P < 0.05$), a lower lactate threshold ($P < 0.05$) and an increased blood lactate concentration after the short running test ($P < 0.05$). For experimental subjects who used the weighted vests for training sessions, lower lactate thresholds and improved running time to exhaustion were attained. This group also improved the vertical velocity when running up stairs and increased $\dot{V}O_2$ during submaximal running after training with the weighted vests.

The results indicated that the aerobic performance characteristics of the experimental subjects were increased and the anaerobic energy metabolism of muscles was enhanced. The authors discussed how extra load training had a negative effect on running economy for groups who wore the weighted vests. During ordinary life and low intensity distance running, slow twitch (ST) muscle fibers are those mainly recruited. Fast twitch muscle fibers are increasingly recruited when the intensity of exercise exceeds the anaerobic threshold. It is believed that the increased mechanical and physiological strain induced by additional loading enhanced the recruitment of fast twitch fibers at a lower intensity of exercise than when training without added load.

To examine the effects of wearing weighted vests during military training, Swain et al., (2010) had physically active, young adult civilians placed in a modified recruit training program for 6 weeks. Participants wore weighted vests (4-5 kg for 2 weeks, and 8-10 kg for 4 weeks) and trained for 1 hour a day, 4 days per week with much emphasis placed on stair climbing and lower body calisthenics and strengthening. Improvements in uphill treadmill performance (6.8% vest, 3.0% control) and maximal oxygen consumption (10.7% vest, 6.8% control) were approximately twice as much in the vest compared to control group, however these differences did not reach statistical significance. This study emphasized much of the training regimen on lower body strengthening using body weight in addition to the weight of the vest. Consequently, skeletal muscle adaptation from this program may have contributed to the insignificant findings for the cardiorespiratory tests. Furthermore, this study did not indicate the relative intensity of the aerobic training component. This study was able to demonstrate that physical fitness could increase by wearing a weighted vest for physically active, young adults.

Faigenbaum, McFarland, Schwerdtman, Ratamess, Kang and Hoffman (2006) examined the acute effects of 4 warm-up protocols with and without a weighted vest on anaerobic performance in female high school athletes. The athletes engaged in 10 minutes of either static stretching (SS), moderate-intensity to high-intensity dynamic exercise (DY), moderate-intensity to high-intensity dynamic exercise with a vest weighted with 2% of body mass (DY2), or moderate-intensity to high-intensity dynamic exercise with a vest weighted with 6% of body mass on vertical jump, long jump, seated medicine ball toss, and 10-yard sprint. Vertical jump performance was significantly greater after DY and DY2 compared with SS, and long jump performance was significantly greater after DY2 compared with SS. No significant differences between trials were observed for the seated medicine ball toss or 10-yard sprint. Furthermore, DY2 may be the most effective dynamic warm-up for enhancing jumping performance in high school female athletes. Long jump performance improved by 12.5% and vertical jump performance improved by 13.5% with DY2. To the researcher's knowledge, this was the first study assessing the acute effects of 4 warm-up protocols, with and without a weighted vest, on anaerobic performance. The portability of a weighted vest enhances the practical applicability of this device, and future authors should examine the short-term and long-term effects of different dynamic warm-up protocols with a weighted vest on performance.

Shaw and Snow (1998) determined if weight-bearing exercises with added resistance from weighed vests would improve dynamic balance, muscle strength and power, and bone mass in postmenopausal women, thereby reducing risk for falls and hip fracture. Exercise sessions were 1 hour, three times per week, for 9 months with or without weighted vests. The vests were weighted according to participant's body weight and were increased based on tolerance and phase in the exercise program. Significant improvements were observed for indices of lateral stability, lower-body muscular strength (16-33% increase), muscular power (13% increase), and leg lean mass (3.5% increase) in exercisers compared to controls ($P < 0.05$). No significant changes were detected for femoral neck bone mass in exercisers or controls at the conclusion of the trial. The authors concluded that lower body exercise, using a weighted vest for resistance, provides an effective means of improving key indices of falls in postmenopausal women.

Weighted Military Equipment

Swain et al. (2010) described how throughout history, military personnel have used personal protective equipment (PPE) in order to reduce the risk of serious injury during combat. Few studies have investigated the effects of loaded marching, and little studies have examined the use of PPE or weighted vests during military training. Weighted vests have been used in the training of civilians, both to improve the physical conditions and bone density of elderly subjects, and to improve the performance of athletes.

The researchers hypothesized that wearing weighted vests during military training would enhance physical performance during tasks when wearing PPE. Physically active, young adult civilians placed in a modified recruit training program participated in this study. Participants were matched for gender, and several test variables (treadmill time, maximal oxygen consumption, push-ups, sit-ups, 3-mile run, and body fat) before being randomized to one of two groups with or without the simulated PPE.

The PPE was composed of a helmet and a vest that contained rigid ceramic plates for the chest and back. The vest came in different sizes to provide an appropriate fit (small, 7.7 kg; medium 8.2 kg; large, 10 kg). Personal protective equipment mass varied somewhat among subjects (but did not differ between groups). Cardiorespiratory testing included pulmonary function and a maximal incremental treadmill test. Field-testing included, in sequence, maximum push-ups in 2 min, maximum sit ups in 2 min, maximum pull-ups to fatigue, and a separately scheduled 3-mile run. Training was conducted for 6 weeks at 1 hour a day, 4 days per week under the supervision of a certified strength and conditioning specialist. The training plan was based on Marine recruit training, but modified to provide more lower body extension work (such as squats and lunges) and by replacing much of the running with stair climbing. In addition, each group performed the Marine Physical Readiness Test (PRT), which is a standard military assessment done without equipment.

The researchers found that both groups significantly improved PRT scores (8.4% 3-mile run, 28-38% calisthenics) and an agility drill (4.4%). Significant improvements in uphill treadmill performance (6.8% vest, 3.0% control) and maximal oxygen consumption (10.7% vest, 6.8% control) were approximately twice as much in the vest versus control group, although these differences did not reach significance ($P = 0.16$ and 0.13, respectively).

The researchers concluded that a training program using vests with a mass of approximately 10 kg resulted in significant increases in several physiological and performance measures. It was suggested that training with more heavily loaded vests for a longer period of time should be investigated.

Majumdar, Srivastava, Purkayastha, Pichan and Selvamurthy (1997), investigated the physiological effects of wearing two different body armors (BA) weighing 9.0 kg and 11.0 kg on the pulmonary function and physical work capacity of male security personnel working in hot humid and comfortable environmental conditions. The BA consisted of front and back metallic plates, made up of mixed steel alloy, with foam padding properly known as “Jackal” steel. The design of the BA was similar to a double pack and when worn, the armor remained very close to the trunk and body’s center of gravity. Participants performed treadmill exercise and pulmonary function tests in the laboratory in addition to a step test in hot, humid exposure in a climatic chamber. Heart rate, minute ventilation, and oxygen uptake $\dot{V}O_2$ while wearing the 11.0 kg BA increased significantly ($P < 0.01$) as compared no body armor during the treadmill exercise. The differences in magnitude were 15 bpm, 9.41 $LO_2 \cdot min^{-1}$ and 6.0 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ respectively for HR, V_E, and $\dot{V}O_2$. In hot humid exposure, the HR and mean skin temperature with 11.0 kg BA also increased significantly ($P < 0.05$) as compared to without wearing it during exercise. Pulmonary functions deteriorated significantly while wearing BA and decreased with an increase in the weight of the armor. The authors discussed two important variables, namely tightness and weight of the BA, are likely to be responsible for its effect on pulmonary function. The significant increase in energy cost of physical tasks increases cardiovascular strain in hot humid exposures, and increased restrictive ventilatory effects which have been found when BA is worn, have important practical implications.

The Acute Physiological Effects of Load Training

Buitrago, Wirtz, Yue, Kleinöder and Mester (2012) examined the acute physiological and metabolic response to one bout of exhaustive bench press exercise with four different exercise modes and different external loads. Subjects performed bench press exercise at 55% (low), 70% (mid), and 85% (high) of their 1-repetition maximum for as many repetitions as possible and in four training modes: 4-1-4-1 (4-s concentric, 1-s isometric, 4-s eccentric and 1-s isometric successive actions) 2-1-2-1 (2-s concentric, 1-s isometric, 2-s eccentric and 1-s isometric successive actions), 1-1-1-1 (1-s concentric, 1-s isometric, 1-s eccentric and 1-s isometric successive actions), or MAX (maximum velocity concentric, 1-s isometric, 1-s eccentric and 1-s isometric successive actions). Oxygen uptake (pre- and post exercise), maximum blood lactate concentration, heart rate, number of repetitions, exercise time, and accumulated lifted mass were recorded and calculated. The researchers found that each of the exercise loads had a significant effect on repetitions (i.e., low>mid>high). A significant increase in repetitions was obtained exercising at a faster mode except from 1-1-1-1 to MAX. Exercise time significantly decreased with increasing load and faster mode. Mass that could be lifted decreased significantly with increasing load but increased with a faster mode with the exception of 1-1-1-1 to max. Mode had a significant effect on $\dot{V}O_2$, oxygen consumption during exercise, and on blood lactate. The researchers concluded that physiological responses on different resistance exercises depend on both the load and velocity mode.

Exercise Prescription

Load training with external load carriage systems has biomechanical, metabolic, and cardiorespiratory effects among healthy individuals and military personnel (Knapik et al., 1996). The individuals who were engaged in physical activity with load carriage systems improved performance after training with loads. It becomes apparent that load training may be beneficial for individuals who do not meet physical activity recommendations suggested by the ACSM, AHA and CDC.

Emerenziani, Migliaccio, Gallotta, Lenzi, Baldari and Guidetti, (2013) cited exercise prescription recommendations for overweight or obese individuals according to previous literature investigating this topic. It was suggested that exercise under guidelines can be safely performed by obese subjects depending upon their habitual physical activity, physical function, health status, exercise responses, and stated goals. Based upon the health goals, a structured exercise program with different types of exercise would be feasible for safety and health benefits. Aerobic exercise has been commonly used to reach weight loss goals. This type of exercise is usually based on a percentage of maximum heart rate, heart rate reserve, rating of perceived exertion, maximal oxygen consumption and for unhealthy subjects, peak oxygen consumption.

Type of exercise was explored by Guelfi, Donges and Duffield (2013), who investigated the effects of aerobic training or resistance training compared to a control on training, perceived hunger and fullness among inactive, overweight and obese men over 12 weeks. Three exercise sessions each week were matched for intensity and duration which were progressively increased from 40 minutes at the beginning of the study, up to 60 minutes by the end of the 12 week period. Aerobic training consisted of a combination of stationary cycling and elliptical cross training. Resistance training involved exercises for each major muscle group of the body (i.e., chest press, shoulder press, rows, lat-pulldown, leg curls, machine squats or deadlifts).

The researchers discovered that cardiorespiratory fitness improved significantly ($P < 0.001$) in the aerobic group while it remained unchanged in the resistance group and control group after the 12-weeks of training. Lower body strength improved in both the aerobic and resistance training group ($P < 0.001$), but the improvement was greater in the resistance training group ($P < 0.001$) while there was no change in the control group. Upper body strength improved in the resistance group only ($P < 0.001$). According to Dual X-ray Absorptiometry (DXA) analysis for body composition following the 12 week exercise programs, there was a significant decline in body mass, BMI, and fat mass ($P < 0.05$), but not lean body mass in the aerobic group. In contrast, the resistance training group did not alter total body mass or BMI, but had an increased lean body mass and reduced fat mass ($P < 0.05$). Lastly, there was no difference in perceived hunger or fullness in any group.

The researchers noted that their findings could have implications for weight control. They suggested that aerobic modes of exercise could be promoted over resistance exercise for weight control based on the higher energy expenditure per unit of time.

Summary

Weighted load carriage systems in the form of personal protective equipment, backpacks, vests or sports apparel have biomechanical and human performance implications. Previous literature has indicated that the load type and positioning can negatively affect human gait and increase the energy costs associated with physical activity or exercise. In addition, greater stresses are imposed on the cardiorespiratory system when wearing weighted load carriage systems, which may bring training implications in relation to human performance. Previous investigations examining the acute physiological adaptations to load training assert that there could be favorable changes in body composition and cardiorespiratory capacities. This may include increases in lean mass, decreases in fat mass, increases in strength and improved aerobic endurance. These favorable changes induced from load exercise training become apparent for those who do not meet the physical activity recommendations provided by the American College of Sports Medicine, American Heart Association, and the Centers for Disease Control and Prevention. These organizations stressed that regular physical activity or exercise can result in improved health over time.

Chapter 3

Methods and Procedures

The purpose of this study was to investigate the effects of wearing a uniformly-weighted exercise training suit on $\dot{V}O_{2max}$, blood pressure, heart rate, rating of perceived exertion (RPE), tympanic membrane temperature, and leg strength during a 6 week aerobic training intervention among previously sedentary individuals. This study was reviewed and pre-approved by the Cal Poly Human Subjects Committee on December 3, 2014.

Subjects

Twenty-one male Cal Poly students aged between 18-32 years, height between 165.1- 188.0 cm, and body mass indexes (BMI) of 18-30 $kg \cdot m^{-2}$ were recruited to conduct this study. Criteria for inclusion in the study included that participants met the "Low-Risk" category for cardiovascular, pulmonary, and/or metabolic disease as described by the American College of Sports Medicine (ACSM): "Individuals classified as those who do not have signs/symptoms of, or have been diagnosed with cardiovascular, pulmonary, and/or metabolic disease and have no more than one risk factor. The risk of an acute cardiovascular event in this population was low, and a physical activity/exercise program could be pursued safely without the necessity for medical examination" (American College of Sports Medicine, 2010, p. 22). Furthermore, participants were untrained and free of supplements or medications that altered body composition, human performance, or physiologic or metabolic responses to human movement. Each participant reported that they had not participated in an exercise or physical activity program in the previous month. Special criteria for the participants were that they "desired to get into an exercise program." Each participant anticipated starting an exercise program for physical, psychological, or health benefits within the next month.

Pilot Testing

Pilot testing was conducted before the initiation of the study in order to evaluate the effectiveness and feasibility of each protocol and assessment tool utilized. Two $\dot{V}O_{2max}$ tests were conducted with the exercise suit using the Bruce protocol on a treadmill (Kaminsky & Whaley, 1998). During these tests, heart rate and blood pressure were monitored using a protocol from the Cal Poly "Physiology of Exercise" course. Tympanic membrane temperature was monitored as well and implemented into the standardized protocol. Heart rate and blood pressure were determined using digital telemetry, sphygmomanometry and a stethoscope, respectively. Tympanic membrane temperature was determined using a Braun^{TM} ThermoScan® ear thermometer (Braun, Kronberg, Germany). This infrared tympanic thermometer met the American Society for Testing and Materials (ASTM) accuracy requirement specified in ASTM standard E1965-98 as it pertained to infrared thermometers and was cited for reliability for accurately estimating core temperature (Nimah, Bshesh, Callahan & Jacobs, 2006). These assessments were during rest, the last minute of each exercise stage (3, 6, and 9 min), and the first and fifth minutes after volitional exhaustion (rest period), which was one of the determining factors for completion of the $\dot{V}O_{2max}$ test. Rating of perceived exertion (RPE) was determined using the Borg scale (6-20) during the last minute of each exercise stage of the Bruce protocol (Borg, 1982; Kaminsky & Whaley, 1998). After the two successful $\dot{V}O_{2max}$ tests it was determined that the protocols and assessments used were feasible under certain conditions.

In order to obtain blood pressures during the preliminary $\dot{V}O_{2max}$ tests, a 15.24 × 15.24 cm hole was cut into the exercise suit on the left antecubital region of the arm sleeve. Before putting on the suit, the blood pressure cuff was fastened to the participant's left arm slightly above the antecubital region so that the blood pressure technician could accurately place the tunable diaphragm on the brachial artery while the exercise suit was on and worn to the manufacturer's specifications. The dial was taped on the exercise suit medially to the participant's left arm approximately halfway between the acromion and olecranon processes. The blood pressure technician held the bulb during the two tests. It was determined that recording blood pressures during the last minute of the first and second submaximal exercise stage of the Bruce protocol was feasible for this study (Kaminsky & Whaley, 1998). In addition, blood pressures were recorded at the last and fifth minute after $\dot{V}O_{2max}$ for safety purposes. This procedure was implemented to ensure that there were no contraindications to maximal graded exercise testing (e.g., poor venous return).

Heart rate was determined in a similar fashion using digital telemetry between a T31 Polar^{TM} heart rate sensor and an F1 Polar^{TM} watch but without any exercise suit modifications. The monitor was placed under the participant's shirt at the midline of the sternum and superior to the xyphoid process. The strap was worn comfortably and securely around the trunk so that the monitor did not lose its position for the duration of the testing period. At this point, the participant wore the exercise suit to the manufacturer's specifications with the heart rate monitor and blood pressure cuff under the suit. The watch was secured to the treadmill and displayed the transmitted signal from the heart rate monitor in beats per minute (bpm).

Additional pilot work was conducted at the Cal Poly Recreation Center to assess the effectiveness of the Path WoodWay, Inc. Treadmills (WoodWay USA, Waukesha, Wisconsin), which were used for the 6 week exercise intervention. Two pilot exercise sessions were conducted with and without the exercise suit in order to determine the sequencing of assessments and if the treadmills were accurate in determining heart rate from the T31 Polar heart rate sensor. Due to the treadmills' spacing, capacity, and restrictions, it was determined that tympanic temperature and blood pressure assessments had to be taken off the treadmill in the middle of the exercise session (20 min). However, blood pressure and tympanic temperature could be measured simultaneously because multiple research assistants were present at the time of the exercise session. In addition, the exercise suit jacket was taken off partially so that the participants' left arm was free from the jacket sleeve. This enabled the research assistant to conduct a blood pressure assessment. The presence of multiple research assistants enabled quick and accurate assessments so that the participant could continue the exercise session on the treadmill with or without the exercise suit.

The F1 Polar watch was brought to the two pilot exercise sessions to compare heart rate values with the Path WoodWay treadmills and with the exercise suit. The research assistant secured the watch to the treadmill's handle railings before the participant started the exercise session with the T31 Polar heart rate sensor. After the treadmill was activated, it quickly determined and displayed the heart rate values on the display screen from digital telemetry. The heart rate values were then compared to the F1 Polar watch, which were analogous with and without the exercise suit. However, during one of the pilot exercise sessions it appeared that the treadmill overestimated heart rate values during the beginning of the warm up period (0-5 min). Because of this finding, it was determined that the watch was to be secured to the treadmill railing for each exercise session because it provided greater heart rate accuracy.

A maximal, 1-repetition leg press pilot test was conducted in the Cal Poly Recreation Center using a LifeFitness^{TM} Insignia Series leg press machine. It was determined that the machine was feasible for the pre- and post leg strength assessment.

Equipment

Body composition was determined using Dual X-ray Absorptiometry (DXA; GE Lunar iDXA, GE Healthcare, Bucks, UK). DXA determined lean mass, fat mass, total % body fat and bone mineral density in the Nutrition and Health Assessment Laboratory at Cal Poly. A portable stadiometer (SECA, Hamburg, Germany) determined height to the nearest 0.1 cm and a digital scale (MedWeigh digital scale, model MS-3200) determined weight to the nearest 0.1 kg.

In the Webb Human Performance Laboratory, $\dot{V}O_{2max}$ was determined using indirect calorimetry by participants running on a treadmill (Trackmaster, Full Vision Inc., Newton, Kansas; Q 65, Quinton Instrument Company, Seattle, Washington) to the Bruce protocol (Kaminsky & Whaley, 1998). Gas analysis was performed using a TrueOne 2400 metabolic measurement system (Parvo Medics, Sandy, Utah), which was a computerized system that used a Hans Rudolf 3813 (Kansas City, MO) pneumotachometer to measure ventilation. It was also a mixing chamber system that used a paramagnetic oxygen analyzer and an infrared, single beam, single wavelength carbon dioxide analyzer (Crouter, Antczak, Hudak, DellaValle & Haas, 2006). Before initializing the $\dot{V}O_{2max}$ test, the gas analyzer was calibrated according to the manufacturer's specifications, which consisted of room air auto-calibration and a two-point gas calibration with a single gas tank. The flow meter was calibrated with a 3 L Hans Rudolf 5530 series syringe, which involved a series of different flow rate stroke calibrations (Crouter et al., 2006).

Heart rates were transmitted using a T31 Polar^{TM} heart rate sensor to an F1 Polar^{TM} heart rate watch and receiver (Polar^{TM}, model 94035939.02). Blood pressure was measured using sphygmomanometry at rest and during the Bruce protocol (Kaminsky & Whaley, 1998). Temperature was recorded using the Braun^{TM} ThermoScan® tympanic thermometer. A nose clip and headgear, which secured a 1-way Hans Rudolf valve to a rubber mouthpiece were given to participants and worn throughout the $\dot{V}O_{2max}$ test for oxygen and carbon dioxide analysis.

A LifeFitness^{TM} Insignia Series leg press machine was used to determine maximal 1-repetition leg extension in the Cal Poly Recreation Center, which was where the exercise conditioning sessions occurred.

These exercise sessions were performed on six of the same Path WoodWay^{TM} treadmills. Exercise sessions also occurred in the Webb Human Performance Laboratory with the same treadmills used for the VO_{2max} tests.

Participants wore a t-shirt and gym shorts with athletic shoes or the same clothing under a 4.54 kg uniformly-weighted exercise suit designed by Athlotek, L.L.C. The exercise suit covered a person's whole body like a snug jacket and pants so that the hands, feet, and neck were free of contact (Figure 1).

Figure 1: The Uniformly-Weighted Exercise Suit (5.45 kg)

The thin and flexible fabric, known as Athlotex^{TM}, had a uniform weight distribution of a certain weight·cm^{-2}, it combined biaxial stretching, breathability and aesthetic appearance for its tailoring into exercise garments with different weights. The Athlotex^{TM} fabric was a laminate composite fabric of Spandex with other synthetic and natural fibers and a thermoplastic polyurethane in which the uniformly distributed weights, in the form of small stainless steel beads, were an integral part of the fabric.

Procedures

All procedures, possible risks and benefits, locations, and required time for this study were explained to participants verbally and through an informed consent document (Appendix A). In addition, participants were required to complete the Canadian Society for Exercise Physiology's PAR-Q and YOU health history questionnaire (Appendix B), a medical history questionnaire (Appendix C), and a Paffenbarger physical activity questionnaire (Appendix D) for inclusion criteria and prescreening requirements.

After meeting inclusion criteria, 21 "low-risk," untrained males participated in the study. A verbal and written explanation of the study timeline was provided for scheduling purposes. Participants were notified that the first and last weeks of this study were for pre- and posttests. Between these two periods were 3, 40 minute exercise sessions on nonconsecutive days each week for 6-weeks, totaling to 8 weeks. Participants scheduled and completed a series of pretests to determine two body composition assessments, two cardiorespiratory fitness pretests, and a maximal 1-repetition leg press for the first week.

Body composition analysis using hydrostatic densitometry was used to determined fat mass and fat-free mass. DXA analysis was also used to determine total body fat percentage (% fat) , lean mass (kg), and bone mineral density ($g \cdot cm^{-2}$). These were completed before the two cardiorespiratory fitness pretests. For each body composition assessment, participants were instructed to avoid heavy physical activity and to fast for 4-5 hours prior to the analysis. They were also instructed to avoid calcium supplement consumption on the day of the DXA analysis.

Upon completing the two body composition assessments, two cardiorespiratory fitness pretests ($\dot{V}O_{2max}$) were scheduled and completed on nonconsecutive days during the first week using the standard Bruce Protocol (Kaminsky & Whaley, 1998; Appendix E). The first pretest was done without the uniformly-weighted exercise suit and the second test was performed with the suit. Before the test, each participant was familiarized with all the equipment and how to use the Borg Scale of Rating of Perceived Exertion (6-20 scale) during exercise (Borg, 1982; Appendix G). Blood pressure and heart rate were monitored before, during, and after the tests as well. Criteria for terminating $\dot{V}O_{2\max}$ tests were meeting 3 of these 5 indicators: plateau in $\dot{V}O_{2\max}$, respiratory exchange ratio greater than or equal to 1.15, rating of perceived exertion greater than or equal to 18, heart rate within 10 beats per minute of predicted maximal heart rate, or participant requested to stop test.

A 1-repetition maximal (1-RM) leg extension test followed the ACSM protocol for muscular strength (Appendix H) and was completed after both body composition analysis and each $\dot{V}O_{2\max}$ pretest. All described pretests were completed by the participants again, except for the second $\dot{V}O_{2\max}$ test, at the end of the 6 week exercise protocol.

All subjects were matched for height, weight, and aerobic capacities so they could be allocated into one of two groups aerobically exercising with or without the uniformly-weighted exercise suit for 6 weeks.

Each participant scheduled 3 exercise sessions on nonconsecutive days each week, for six weeks. The exercise sessions were held on Mondays, Wednesdays, and Fridays for 1 hour time slots from 8-12 P.M. Participants could choose times on the hour for each exercise session, which were 40 minutes and consisted of jogging on a treadmill at 60%-70% of maximum heart rate determined by the $\dot{V}O_{2\max}$ pretests (Appendix I). Before the start of each session, participants' weight, heart rate, blood pressure and tympanic membrane temperature were recorded. After these initial assessments, participants started the exercise session with a 5 minute warm up on the treadmill at a self-selected, moderate walking speed. After this period, treadmill grade and speed were self-selected until participants reached 60%-70% of maximal heart rate and continued at that work rate for 30 minutes. After 30 minutes at that pace, participants adjusted the treadmill for the 5 minute cool down period, which was a slow to moderate walking pace at 0% grade. Participants completed the exercise session after the 5 minute cool down.

Heart rate, blood pressure, and core temperature were assessed and recorded during the exercise sessions at 0, 20, and 40 minutes using the aforementioned methods. Heart rate was also recorded at 5 and 35 minutes as well. This was instilled to keep participants at their 60%-70% max heart rate. This protocol was the same for all exercise sessions during the 6 weeks.

All exercise sessions followed the ACSM Guidelines for Exercise Testing and Prescription and their guidelines for General Indications for Stopping an Exercise Test in Low-Risk Adults (American College of Sports Medicine, 2010, p. 83). Two kinesiology graduate research assistants, one kinesiology senior undergraduate student, and four students enrolled in “The Assessment Team” (A-Team; KINE 290-02) were trained to conduct all assessments employed in this study by Trevor Curry. Curry, along with the trained research assistants, supervised all pretests, posttests, and exercise sessions. Both testing facilities featured emergency telephone numbers visible for researchers who were CPR, AED, and First Aid certified. The uniformly-weighted exercise suits were washed after the third week of the 6 week exercise protocol with a mild detergent and hung dried before next use. Participants were given fivedollars after they completed all three exercise sessions for each week, summing to a maximum of $30 after six weeks of training.

Statistical Methods

All data were recorded and manually entered twice into two different Microsoft^{TM} Excel spreadsheets. All participant identification numbers were entered into a single row while all dependent measures for each pretest, the 6 week exercise protocol, and posttests were entered into individual columns respectively. These two spreadsheets were then compared so that any identified errors could be corrected.

Thereafter, a single spreadsheet was saved as a comma-separated values (csv) document and imported into JMP Stats version 11.2 (SAS Institute, Cary, NC) for statistical analysis. Descriptive statistics were calculated for variables used in this study including means (M) and standard deviations (SD) for participants' age, height, weight, BMI, body composition (total body fat %, lean mass, fat mass, bone mineral density), initial $\dot{V}\mathrm{O}_{2\max}$ and leg strength (Table 1).

A multivariate regression analysis was conducted to explain the changes in $\dot{V}\mathrm{O}_{2\max}$, which was the difference between the post and pre- $\dot{V}\mathrm{O}_{2\max}$ test for each participant. Six explanatory variables were used to explain the change in $\dot{V}\mathrm{O}_{2\max}$ which were group (with or without the suit), pre $\dot{V}\mathrm{O}_{2\max}$, pre leg strength, pre total body percentage fat (% fat), pre lean mass (kg), and group interacted with pre $\dot{V}\mathrm{O}_{2\max}$.

Dependent t-tests were used to compare the means of the differences of the change (post-pre) for lean mass, fat mass, total body fat (% fat), weight, BMD, leg strength and treadmill time to exhaustion. In addition, a multivariate regression analysis was conducted to see if the changes in lean mass, fat mass and total body percentage fat (% fat) could be explained by group, pre values for lean mass and total body fat (% fat) or group interacted with pre lean mass or total body percentage fat (% fat).

A repeated measures MANOVA was used to identify differences for oxygen consumption ($\dot{VO}_2$), respiratory exchange ratios (RER), systolic blood pressures (SBP), diastolic blood pressures (DBP), RPE, and tympanic membrane temperatures between the two VO_{2max} pretests with and without the exercise suit. A dependent t-test was used to compare the means for the treadmill times to exhaustion with and without the exercise suit.

A multivariate regression analysis was used to explain the variance of blood pressures, weight, and tympanic membrane temperature changes across the 6 week exercise intervention. The explanatory variables that could explain the aforementioned changes were group (with or without the exercise suit), participant nested within group, week (1-6), and group interacted with week, which were used for each response variable. Each explanatory variable was calculated as follows: The changes in blood pressures (systolic and diastolic) were the differences between at rest (0 min) and at the middle of the aerobic training period (20 min). This difference was calculated for each exercise training session (Monday, Wednesday and Friday) and then averaged for that week, totaling to 6 different average changes (one for each week) in blood pressure for each participant. The changes in weight were determined by taking the difference before and after each exercise training session and then calculating the average weight change for each week, totaling to six different average weight changes for each participant. The changes in tympanic membrane temperature were determined by taking the difference at rest (0 min) and at the middle of the aerobic training period (20 min) and then calculating the average tympanic membrane temperature change for each week, totaling to 6 different average tympanic membrane temperature changes for each participant.

A repeated measures MANOVA was used to identify differences between heart rates with or without the exercise suit for the first $\dot{V}O_{2max}$ pretest (without the exercise suit) and the $\dot{V}O_{2\max}$ posttest (without the exercise suit) during minutes 3, 6, 9, 12, and 15 of these tests. In this model, group (with or without the exercise suit), test (pretest or posttest), and group interacted with test were used in this analysis.

A 2 × 4 ANOVA was used to identify differences between rate pressure products (heart rate · systolic blood pressure) with or without the exercise suit for the first $\dot{V}O_{2\max}$ pretest (without the exercise suit) and the $\dot{V}O_{2\max}$ posttest (without the exercise suit) during the third and sixth minute of these maximal graded exercise tests. In this model, group (with or without the exercise suit), test (pretest or posttest), and group interacted with test were used in this analysis.

Bonferoni adjustments were made for each multivariate regression analysis. According to Mundfrom, Perrett, Schaffer, Piccone and Roozeboom (2006), "the Bonferoni adjustment divides the nominal significance level, α, by the number of tests being performed simultaneously to prevent the overall level of significance from exceeding the nominal level, α. The adjusted level of significance, in general α/k for k tests, is used to conduct each of the k individual tests." Six explanatory variables were used for the multivariate regression analysis examining $VO_{2\max}$ change. The Bonferoni adjustment for α in this analysis was set at ($P < 0.008$). Three explanatory variables were used for the multivariate analysis examining lean mass, fat mass, and total % body fat change. The Bonferoni adjustment for α in this analysis was set at ($P < 0.01$). Four explanatory variables were used for the multivariate regression analysis examining weight change, changes in blood pressures, and tympanic membrane temperature change. The Bonferoni adjustment for α for this analysis was set at ($P < 0.01$).

The statistical software program JMP 11 had the ability to conduct power analyses, which “calculates the statistical power and other details about a given hypothesis test” (SAS Institute, Cary, NC). For this study, the power analysis option was used to determine the least significant number, which is the total amount of observations or data points that were needed to produced a statistically significant result at ($P < 0.05$) using the initial “standard deviation of the error and the effect size” (SAS Institute, Cary, NC).

Chapter 4

Results and Discussion

Results

Participants

Twenty-one participants were randomly allocated to the group with or without the exercise suit for the 6 week exercise intervention after matching for initial VO_{2max}, height (cm), weight (kg) and leg strength (kg). Descriptive statistics for these variables as well as BMI, total body fat, % fat, lean mass (kg) and BMD for participants before and after the 6 week exercise intervention are reported in means and standard deviations (M ± SD) in Table 1. Some data were excluded due to participant scheduling conflicts and metabolic cart malfunctions which resulted in unreliable data.

Table 1. Participant Characteristics

	Pre-Intervention		
Variable	No Suit (*N*=11)	Suit (*N*=10)	P-value
Age (years)	20.27 ± 1.01	21.3 ± 4.13	0.43
Height (cm)	176.6 ± 6.49	177.67 ± 6.45	0.71
Weight (kg)	80.5 ± 15.93	76.04 ± 10.2	0.46
BMI ($kg \cdot m^{-2}$)	25.69 ± 4.05	24.10 ± 3.11	0.33
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	47.45 ± 7.32	51.92 ± 9.67†	0.25
Body Composition			
DXA Lean Mass (kg)	56.00 ± 8.99	52.91 ± 6.31†	0.40
DXA Fat mass (kg)	20.44 ± 8.45	17.60 ± 7.64†	0.44
DXA Total % Body Fat	25.86 ± 5.91	24.21 ± 7.23	0.58
DXA Bone Mineral Density ($g \cdot cm^{-2}$)	1.3 ± 0.12	1.19 ± 0.14†	0.11
Leg Press (kg)	144.63 ± 35.37	147 ± 37.23	0.83
Treadmill Time to Exhaustion (s)	744.9 ± 99.7	731.4 ± 211.6	0.85

Note: Values are mean±SD
†Some data excluded due to conflict and machine malfunctions

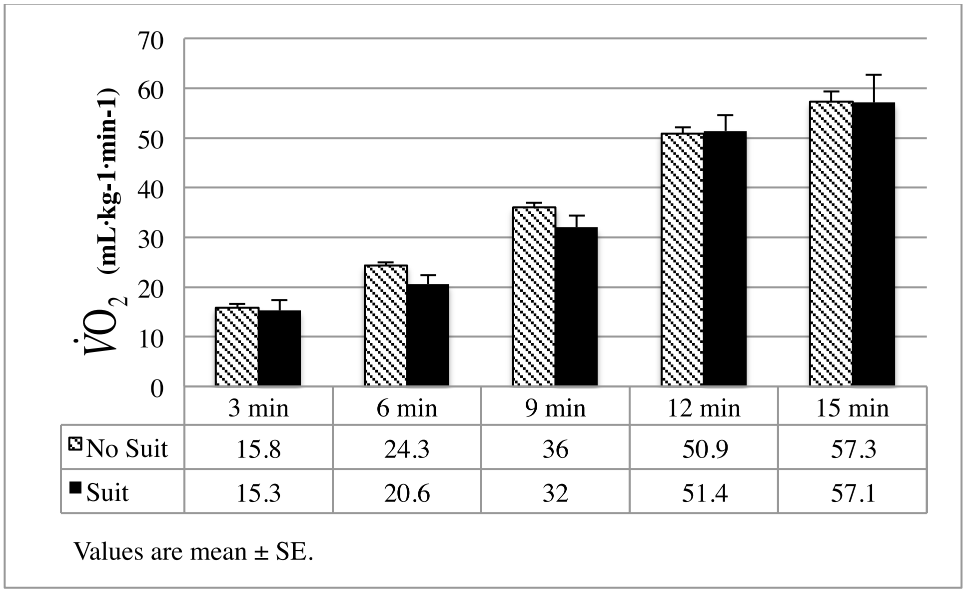
Exercise Testing with the Weighted Exercise Suit

This section will report the measured variables for the two $\dot{V}O_{2max}$ pretests with and without the exercise suit. These variables were oxygen consumption ($\dot{V}O_2$), respiratory exchange ratios (RER), blood pressures (systolic and diastolic), heart rate, tympanic membrane temperature and treadmill time to $\dot{V}O_{2max}$, which were measured incrementally at 3 minute stages during the protocol (Kaminsky & Whaley, 1998).

Oxygen Consumption

It was hypothesized that $\dot{V}O_{2max}$ testing with the exercise suit would result in greater $\dot{V}O_2$ at any given submaximal work rate stage compared to testing without the suit because this suit added 5.45 kg to the subjects' weight. The repeated measures MANOVA revealed that there were no significant differences between $\dot{V}O_2$ consumption at any given exercise stage with or without the exercise suit ($P > 0.05$). There were non-significant differences in $\dot{V}O_2$ between the second (6-minute), third (9-minute), and fourth (12-minute) stage of the Bruce protocol (Kaminsky & Whaley, 1998; Figure 2). The mean $\dot{V}O_2$ at the second stage without the suit was 24.3 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ compared to 20.6 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ with the suit, which resulted in a 3.7 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ difference. The mean $\dot{V}O_2$ at the third stage without the suit was 36 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ compared to 32 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ with the suit, which was 4 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ greater than with the suit. The mean $\dot{V}O_2$ for the fourth stage was 50.91 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ without the suit and 51.4 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ with the suit. The $\dot{V}O_2$ difference between these two was 0.49 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$ ($P > 0.05$). These findings suggest that there could have been a "learning effect" between the two $\dot{V}O_{2\max}$ tests because the research design was not counterbalanced. All participants completed the first $\dot{V}O_{2\max}$ test without the exercise suit followed by 1-week washout period before the $\dot{V}O_{2\max}$ test with the exercise suit. Counterbalancing can control for order effects and other factors that might contribute to the results.

There was a significant difference for $\dot{V}O_2$ across time ($P < 0.0005$). This finding is expected considering the incremental change in intensity for each submaximal work rate, which requires a greater level of oxygen demand and utilization for performance.



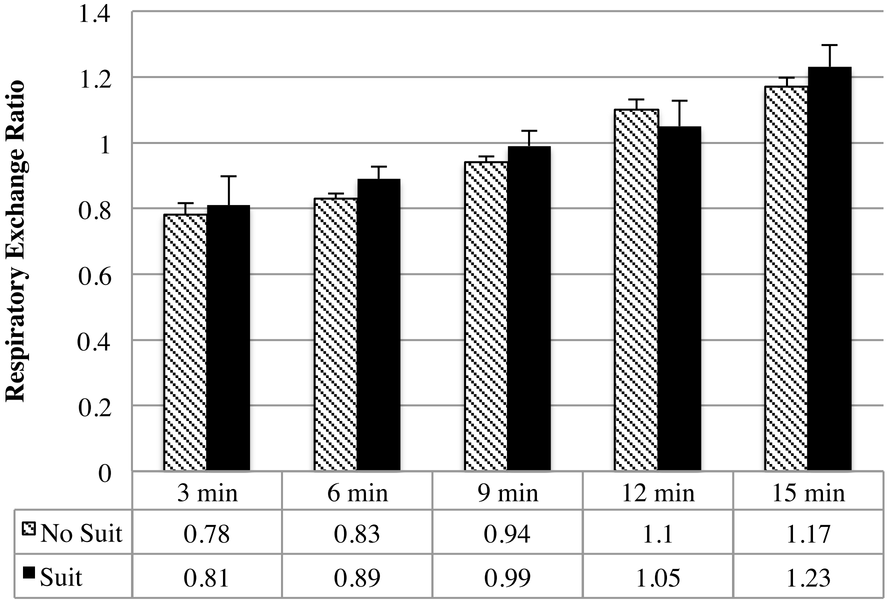
	3 min	6 min	9 min	12 min	15 min
▨No Suit	15.8	24.3	36	50.9	57.3
■Suit	15.3	20.6	32	51.4	57.1

Values are mean ± SE.

Figure 2. Effect of the Exercise Suit on Oxygen Uptake During Maximal Graded Exercise Testing to $\dot{V}O_{2\max}$.

Respiratory Exchange Ratios

It was hypothesized that exercise testing with the exercise suit would induce greater RER values at any given submaximal work rate compared to testing without the suit because the weight of the exercise suit could influence the type of fuel metabolism used for performance. Participants were instructed to avoid eating 2 hours before the maximal graded exercise tests. It appeared that RER values with the exercise suit exceeded RER values without the suit during initial and late submaximal work rate stages, however these differences were not statistically significant ($P > 0.05$) after running a repeated measured MANOVA (Figure 3). There was no difference between maximum RER values suggesting that participants ran to the point of volitional exhaustion for each condition. In addition, there were no statistically significant differences between RER values across time ($P = 0.0583$). This value was close to achieving statistical significance. A greater sample size would have allowed RER to reach statistical significance across time.



	3 min	6 min	9 min	12 min	15 min
▨ No Suit	0.78	0.83	0.94	1.1	1.17
■ Suit	0.81	0.89	0.99	1.05	1.23

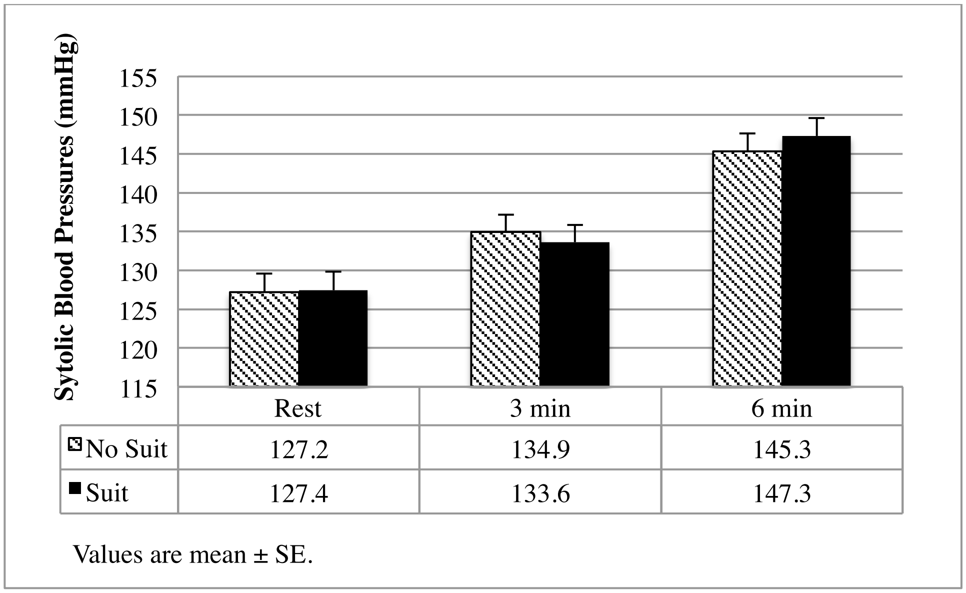
Values are mean ± SE.

Figure 3. Effect of the Exercise Suit on Respiratory Exchange Ratios During Maximal Graded Exercise Testing to $\dot{V}O_{2\max}$.

Blood Pressures

It was hypothesized that exercise testing with the exercise suit would induce greater blood pressures at any given submaximal work rate compared to testing without the suit because of the weight and tight fitting of the exercise suit. The results from a repeated measures MANOVA indicate that there was a statistically significant difference between systolic blood pressures across time ($P < 0.0001$) but no statistically significant differences between systolic blood pressures with or without the suit at any given submaximal work rate ($P > 0.05$), which is displayed in Figure 4. The mean systolic blood pressure without the exercise suit at rest, first, and second stages were 127.2 mmHg, 134.9 mmHg, and 145.3 mmHg and 127.4 mmHg, 133.6 mmHg, and 147.3 without the suit, respectively.

Furthermore, when examining diastolic blood pressures, the results from a repeated measures MANOVA revealed that there were statistically significant differences for diastolic blood pressures across time ($P = 0.0397$) but no statistically significant differences between diastolic blood pressures with and without the exercise suit at any given submaximal work rate stage ($P > 0.05$), which is displayed in Figure 5. It appeared that the exercise suit alone did not affect systolic and diastolic blood pressures during maximal graded exercise testing compared to testing without the exercise suit.



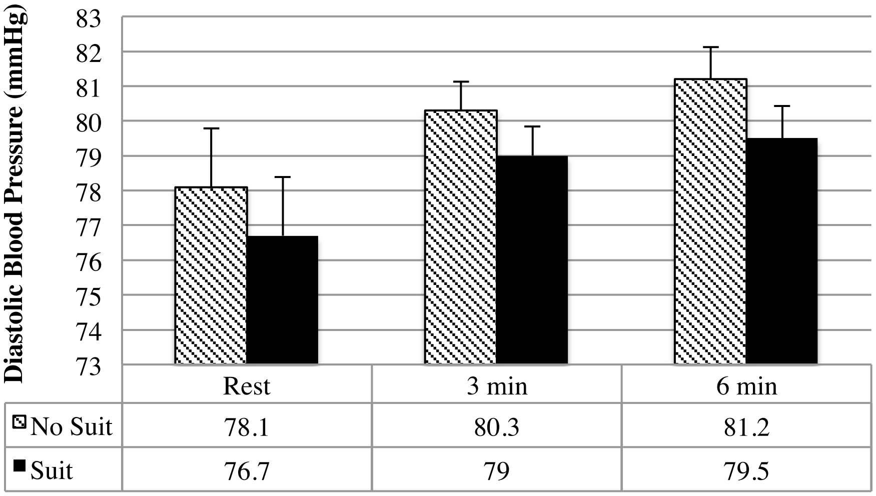
	Rest	3 min	6 min
▨No Suit	127.2	134.9	145.3
■Suit	127.4	133.6	147.3

Values are mean ± SE.

Figure 4. Effect of the Exercise Suit on Systolic Blood Pressures During Submaximal Exercise Stages.

Heart Rates

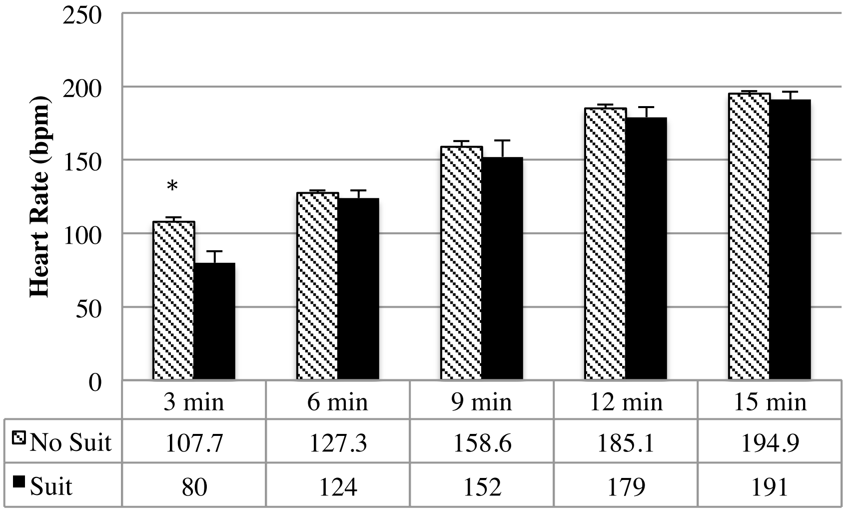
It was hypothesized that exercise testing with the exercise suit would result in greater heart rates at any submaximal work rate stage compared to testing without the suit because the exercise suit added 5.45 kg to the participants' weight. The results from the repeated measures MANOVA suggest that there was a statistically significant difference for heart rate across time (P = 0.0026) and for the first submaximal exercise stage (P = 0.0315) with and without the exercise suit, which is displayed in Figure 6. That is, at the end of the first submaximal work rate stage, the mean heart rate with the suit was 80 bpm and significantly lower than without the suit, which was 107.7 bpm on average. This finding conflicts with the assumption that heart rates with the exercise suit will be greater across all submaximal exercise stages. No other statistically significant differences were found between heart rates with and without the exercise suit across all submaximal exercise stages. The mean values for heart rates without the exercise suit at the first, second, third, and fourth stage were 107.7 bpm, 127.3 bpm, 158.6 bpm and 80 bpm, 124 bpm, 152 bpm, 179 bpm and 191 bpm with the exercise suit respectively.



	Rest	3 min	6 min
▨ No Suit	78.1	80.3	81.2
■ Suit	76.7	79	79.5

Values are mean ± SE.

Figure 5. Effect of the Exercise Suit on Diastolic Blood Pressures During Submaximal Exercise Stages.



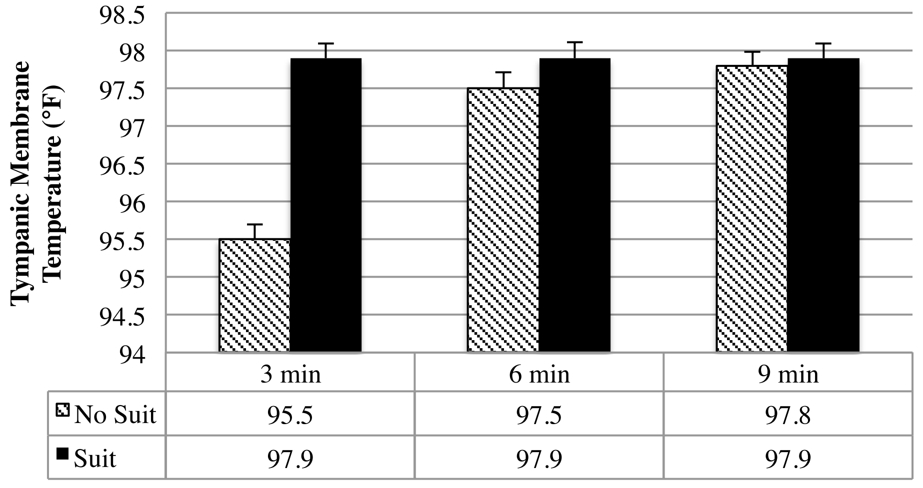
	3 min	6 min	9 min	12 min	15 min
▨ No Suit	107.7	127.3	158.6	185.1	194.9
■ Suit	80	124	152	179	191

Values are mean ± SE. * $P < 0.05$ vs. exercise suit.

Figure 6. Effect of the Exercise Suit on Heart Rates During Maximal Graded Exercise Testing to $\dot{V}O_{2max}$.

Tympanic Membrane Temperatures

It was hypothesized that exercise testing with the exercise suit would result in greater tympanic membrane temperatures at any given submaximal work rate compared to testing without the suit because the exercise suit was full-bodied and composed of dense fabric material that could serve as a thermal barrier. The results from the repeated measures MANOVA indicate that there was no statistically significant difference across time and between submaximal work rate stages with and without the exercise suit (P > 0.05). The mean tympanic membrane temperatures without the exercise suit at the first, second and third exercise stage were 95.5ºF, 97.5ºF, 97.8ºF and 97.9ºF, 97.9ºF, and 97.9ºF with the exercise suit respectively, which is displayed in Figure 7. These findings suggests that tympanic membrane temperatures underestimated actual body core temperatures during exercise.



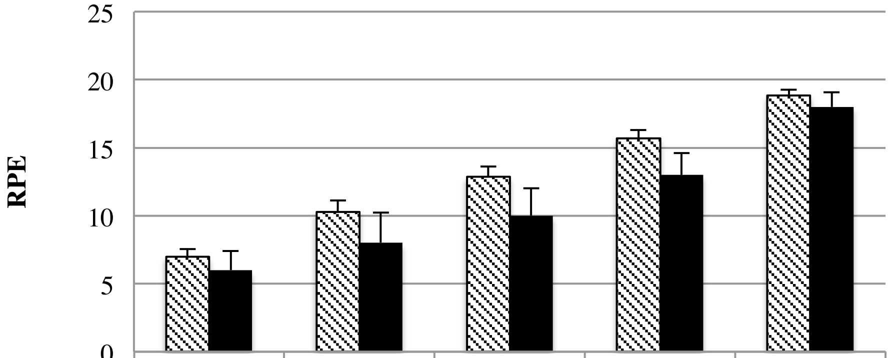
	3 min	6 min	9 min
▨ No Suit	95.5	97.5	97.8
■ Suit	97.9	97.9	97.9

Values are mean ± SE.

Figure 7. Effect of the Exercise Suit on Tympanic Membrane Temperatures During Submaximal Exercise Stages.

Ratings of Perceived Exertion

It was hypothesized that exercise testing with the exercise suit would result in greater RPE scores compared to testing without the exercise suit because the exercise suit added 5.45 kg to the participants' weight. The results from the repeated measures MANOVA indicates that there was only a statistically significant difference across time for RPE (P = 0.0044). There was no difference between the exercise stages with or without the exercise suit, however RPE scores increased proportionally with every increase in intensity from each submaximal exercise stage. These results suggested that participants were able to complete the test until reaching volitional exhaustion without any differences in RPE. Scores for RPE are displayed in Figure 8.



	3 min	6 min	9 min	12 min	15 min
▨ No Suit	7	10.3	12.85	15.7	18.85
■ Suit	6	8	10	13	18

Values are mean ± SE.

Figure 8. Effect of the Exercise Suit on Ratings of Perceived Exertion During Maximal Graded Exercise Testing to $\dot{V}O_{2max}$.

Treadmill Times to Exhaustion

It was hypothesized that exercise testing with the exercise suit would result in faster times to exhaustion compared to testing without the suit because the exercise suit added 5.45 kg to the participants' weight. The results from the dependent t-test that analyzed this indicated that there was no statistically significant difference between treadmill times to exhaustion with or without the exercise suit (P > 0.05). The mean time to exhaustion without the exercise suit was 738.5 s [678, 798] and 714.14 s [654.65, 773.64] with the exercise suit. Treadmill times to exhaustion are displayed in Figure 9.

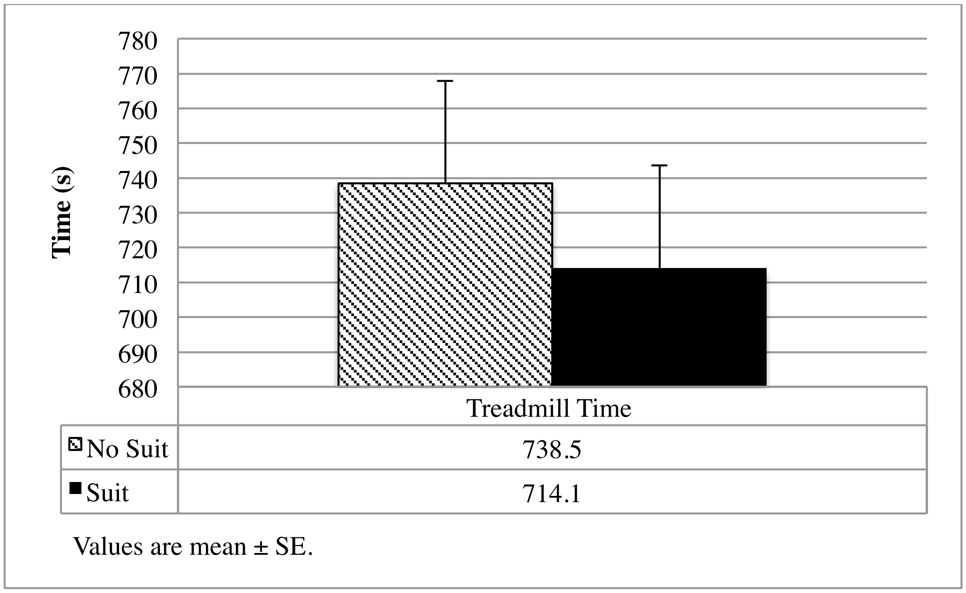


Figure 9. Effect of the Exercise Suit on Treadmill Times to Exhaustion.

Exercise Intervention Changes

This section will report the changes in blood pressures (systolic and diastolic), weight, and tympanic temperatures during the 6-week exercise intervention, which are displayed in Table 3 and Figures 10, 11, 12 and 13. The changes in systolic pressures were determined by the differences of pressures at rest and at 20 min of the aerobic exercise session. The changes in weight were determined by the differences between before and after the exercise session. This was recorded to account for dehydration between the groups. The changes in tympanic membrane temperatures were determined by the differences between at rest and at during the 20 minute mark of the aerobic training session.

Table 2. The Effect of the Exercise Suit on the Average Change for Weight, Blood Pressures and Tympanic Membrane Temperatures Across the Exercise Intervention.

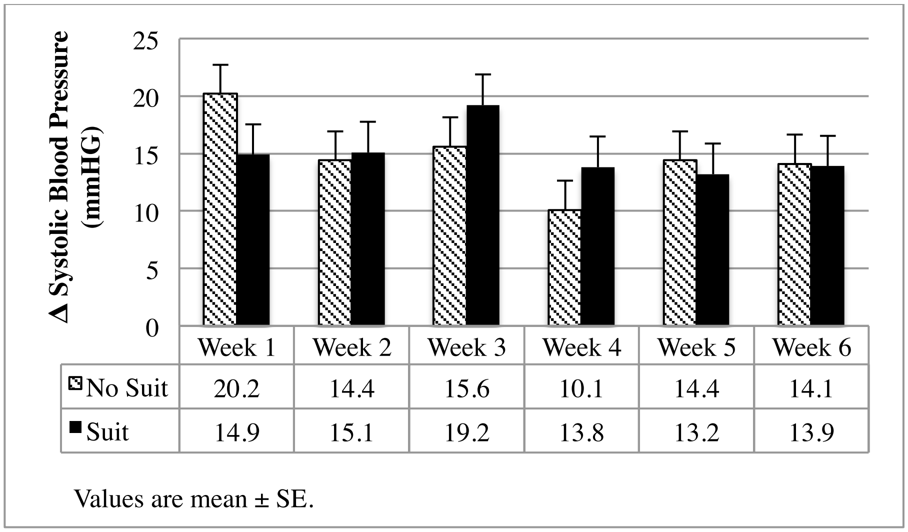
	R^2	Average Change	P-value
Weight (kg)	.55		0.44
No Suit		-0.22±0.26	
Suit		-0.30±0.13	
Systolic Blood Pressure (mmHg)	.33		0.16
No Suit		14.81±8.78	
Suit		15.05±9.31	
Diastolic Blood Pressure (mmHg)	.42		0.08
No Suit		0.66±5.61	
Suit		2.36±6.66	
Tympanic Temperature (ºF)	.55		0.92
No Suit		0.77±0.59	
Suit		0.90±0.55	

Note: Values are Mean ± SD. Total observations for No Suit (n = 66) and Suit (n = 60).

Blood Pressures

The multivariate regression analysis revealed that 33% of the variance from systolic blood pressure changes could be explained by group, participant nested in group, week, and group interacted with week. This model approached, but did not achieve statistical significance (P = 0.052). The averages of the change for systolic blood pressure for the exercise intervention are displayed in Figure 10.

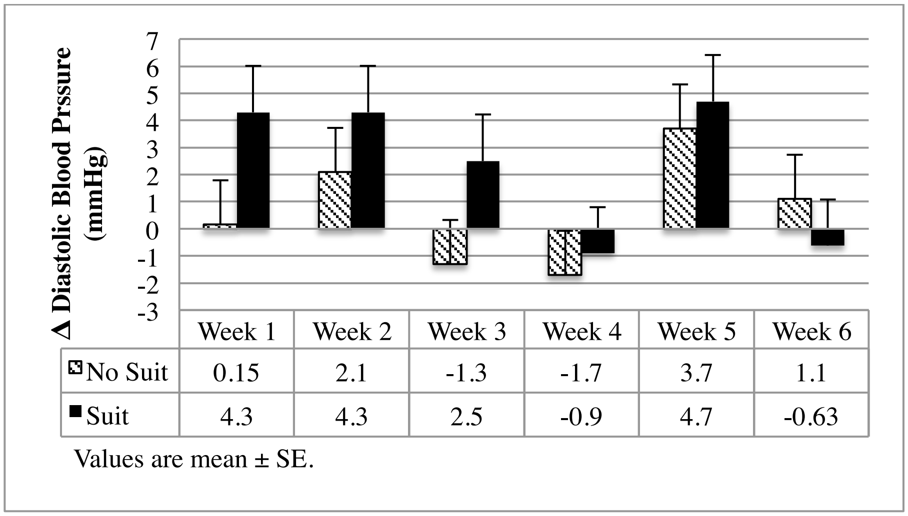
The multivariate regression analysis for diastolic blood pressure changes indicated that 41% of the variance could be explained by group, participant nested in group, week, and group interacted with week, which was statistically significant (P = 0.0016). For this model, only participant nested within group (P = 0.003) was statistically significant. It appears that the changes in diastolic blood pressures were different for each participant. The change in diastolic blood pressure with the exercise suit was non-significant (P = 0.08). It was estimated that the average diastolic blood pressure change when wearing the exercise suit was + 2.4 mmHg [0.87, 7.66] and 0.66 mmHg [-3.1, 3.4] without the exercise suit. The averages of the change for diastolic blood pressures across the exercise intervention are displayed in Figure 11.



	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
▨No Suit	20.2	14.4	15.6	10.1	14.4	14.1
■Suit	14.9	15.1	19.2	13.8	13.2	13.9

Values are mean ± SE.

Figure 10. Effect of the Exercise Suit on Average Systolic Blood Pressure Change During the Exercise Intervention.



	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
▨No Suit	0.15	2.1	-1.3	-1.7	3.7	1.1
■Suit	4.3	4.3	2.5	-0.9	4.7	-0.63

Values are mean ± SE.

Figure 11. Effect of the Exercise Suit on Average Diastolic Blood Pressure Change During the Exercise Intervention.

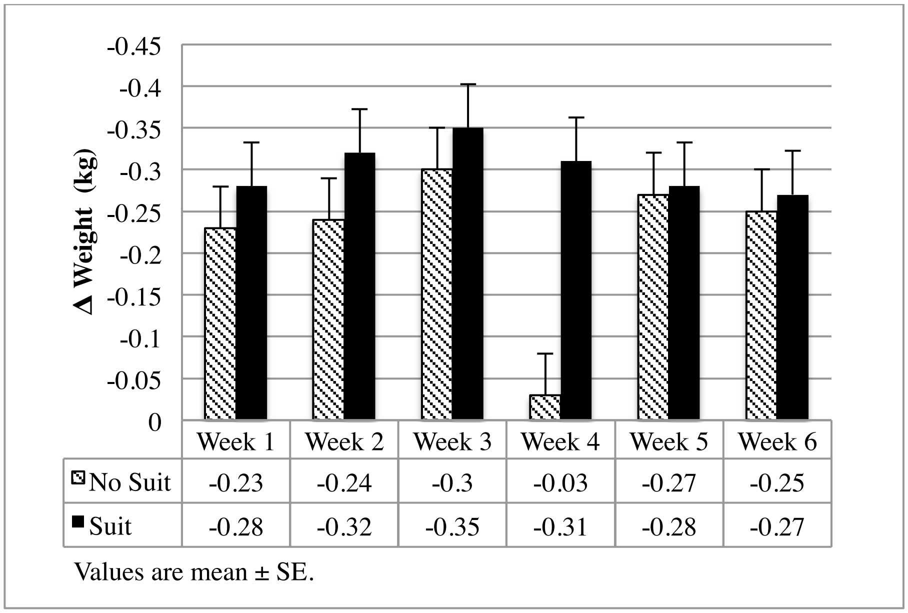
Weight

The multivariate regression analysis for weight change revealed that 55% of the variance was explained by group, participant nested in group, week, and group interacted with week, which was statistically significant (P < 0.0001). Of the explanatory variables, only participant nested within group was statistically significant (P < 0.0001). This finding suggests that individual weight change was independent from wearing the suit or not, the exercise intervention week, and the effects from wearing the suit or not on the week.

The effect of wearing the suit during exercise was non-significant (P = 0.44). The effect of wearing the suit during exercise on average was – 0.3 kg [-0.41, -0.15] and -0.22 kg [-0.34, -0.09] without the exercise suit. The averages for the change in weight between the exercise intervention are displayed in Figure 12. Features of the exercise suit such as full-bodied design, uniformly distributed weight, and breathability might explain weight changes by altering the body's control of thermoregulation. This non-significant finding suggests that there was an estimated sweat loss of 80 mg over 30 minutes. Perhaps the difference would be meaningful with prolonged exercise with the exercise suit.

Tympanic Membrane Temperatures

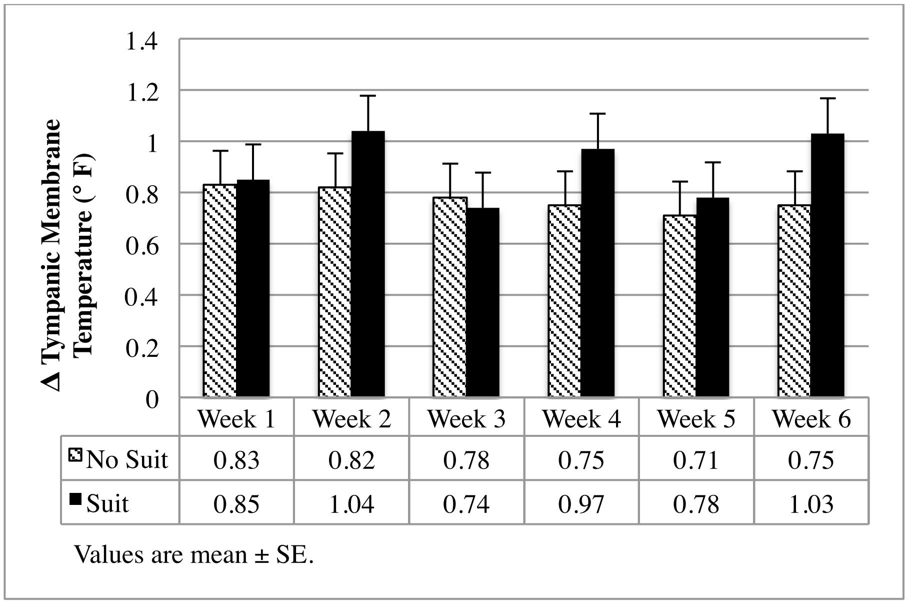
The multivariate regression analysis for tympanic membrane temperature change revealed that 55% of the variance from tympanic change could be explained by group, participant nested within group, week, and group interacted with week, which was statistically significant (P < 0.0001). The only explanatory variable that was statistically significant was participant nested within group (P < 0.0001), which indicates that tympanic temperature changes across the exercise intervention were varied among all participants regardless of group, the week, and group interacted with week. The effect of the exercise suit on tympanic membrane temperature change was non-significant (P = 0.92). The average tympanic membrane temperature change with the exercise suit was + 0.90 º F [0.57, 1.13] and 0.77ºF [0.56, 1.09] without the exercise suit. The averages for the change in tympanic membrane temperature between the exercise intervention is displayed in Figure 13.



	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
▨No Suit	-0.23	-0.24	-0.3	-0.03	-0.27	-0.25
■Suit	-0.28	-0.32	-0.35	-0.31	-0.28	-0.27

Values are mean ± SE.

Figure 12. Effect of the Exercise Suit on Average Weight Change During the Exercise Intervention.



	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
▨ No Suit	0.83	0.82	0.78	0.75	0.71	0.75
■ Suit	0.85	1.04	0.74	0.97	0.78	1.03

Values are mean ± SE.

Figure 13. Effect of the Exercise Suit on Average Tympanic Membrane Temperature Change During the Exercise Intervention.

Training Outcome Changes

The results of this section will report the differences of the change that occurred before and after the 6 week exercise intervention with and without the exercise suit for VO$_{2max}$, body composition, bone mineral density, leg strength, and treadmill time to exhaustion, which are displayed in Table 3.

Maximal Oxygen Uptake ($\dot{V}O_{2max}$)

It was hypothesized that training with the exercise suit would result in a greater $\dot{V}O_{2max}$ change compared to the control condition – no suit. The multivariate regression analysis revealed that 60.8 % of the variance could be explained by the group (with or without the exercise suit), participants' initial $\dot{V}O_{2max}$, initial lean mass, initial total body (% fat), initial leg strength, and an interaction between group and initial $\dot{V}O_{2max}$ for the change in $\dot{V}O_{2max}$ after the 6 week exercise intervention. For this model, none of the explanatory variables were statistically significant predictors for the change in $\dot{V}O_{2max}$ after Bonferonni corrections ($P > 0.008$). An additional multivariate regression analysis was used to predict the change in $\dot{V}O_{2max}$ using five explanatory variables, which were group, participants' initial $\dot{V}O_{2max}$, initial lean mass, initial total body percentage fat (% fat) and initial leg strength. This model could explain 60.6 % of the variance for the change in $\dot{V}O_{2max}$ but none of the explanatory variables were significant ($P > 0.01$). Both multivariate regression models could explain approximately 60% of the variance of the change in $\dot{V}O_{2max}$ but were non-significant.

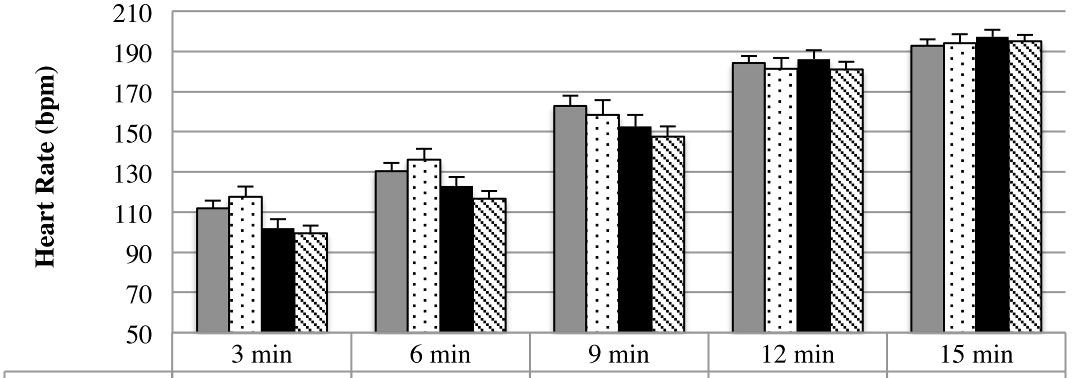
According to the first regression model, the $\dot{V}O_{2max}$ change with the exercise suit was + 2.72 $mlO_2 \cdot kg^{-1} \cdot min^{-1}$ [0.13, 5.31] and + 1.16 $mlO_2 \cdot kg^{-1} \cdot min^{-1}$ [-1.43, 3.74] without the suit.

Heart Rate Change

The changes in heart rate were determined by comparing the heart rates at submaximal work rates (3, 6, 9, 12 and 15 min) during the first $\dot{V}O_{2max}$ pretest and $\dot{V}O_{2max}$ posttest without the exercise suit using a repeated measured MANOVA. This test was conducted to assess any training adaptations that occurred between the exercise intervention. Group (with or without the exercise suit), test (pretest or posttest), and group interacted with test were used in this analysis with a level of significance set at $P < 0.01$. The results for heart rates at 3 minutes indicated that there was no difference for group ($P = 0.02$) test ($P = 0.74$) and test interacted with group ($P = 0.38$). For heart rates at 6 minutes, there was no difference for group ($P = 0.02$), test ($P = 0.74$), and test interacted with group ($P = 0.22$). For heart rates at 9 minutes, there was no difference for group (P = 0.25), test (P = 0.44), and test interacted with group (P = 0.97). For heart rates at 12 minutes, there was no difference for group (P = 0.97), test (P = 0.40), and test interacted with group (P = 0.80). For heart rates at 15 minutes, there was no difference for group (P = 0.82), test (P = 0.90), and test interacted with group (P = 0.70). The heart rate means for this analysis are displayed in Figure 14.

Table 3. Effect of the Exercise Suit on the Change in Selected Variables After the Exercise Intervention.

	R^2	Average Change	P-value
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	0.60		0.41
No suit (n=9)		2.72 ± 4.1	
Suit (n=9)		1.16 ± 3.17	
DXA Lean Mass (kg)	0.04		0.81
No suit (n=11)		-0.099 ± 1.43	
Suit (n=9)		0.132 ± 1.38	
DXA Fat Mass (kg)	0.11		0.31
No suit (n = 11)		-0.27 ± 1.25	
Suit (n=9)		-0.85 ± 1.62	
DXA Total Body (% Fat)	0.15		0.24
No suit (n=11)		-0.27 ± 1.14	
Suit (n=9)		-0.94 ± 1.66	
Weight (kg)	0.03		0.95
No suit (n=11)		-0.24 ± 1.5	
Suit (n=10)		-0.32 ± 2.33	
DXA Bone Mineral Density (g/cm^2)	0.11		0.30
No suit (n=11)		-0.006 ± 0.013	
Suit (n=9)		-0.006 ± 0.017	
Leg Strength (kg)	0.61		0.07
No suit (n=11)		6.2 ± 36.6	
Suit (n=10)		-14.77 ± 26.36	
Treadmill Time to Exhaustion (s)	0.11		0.30
No suit (n=11)		73.63 ± 68.32	
Suit (n=10)		47.8 ± 44.01	
Note: Values are mean ± SD.			



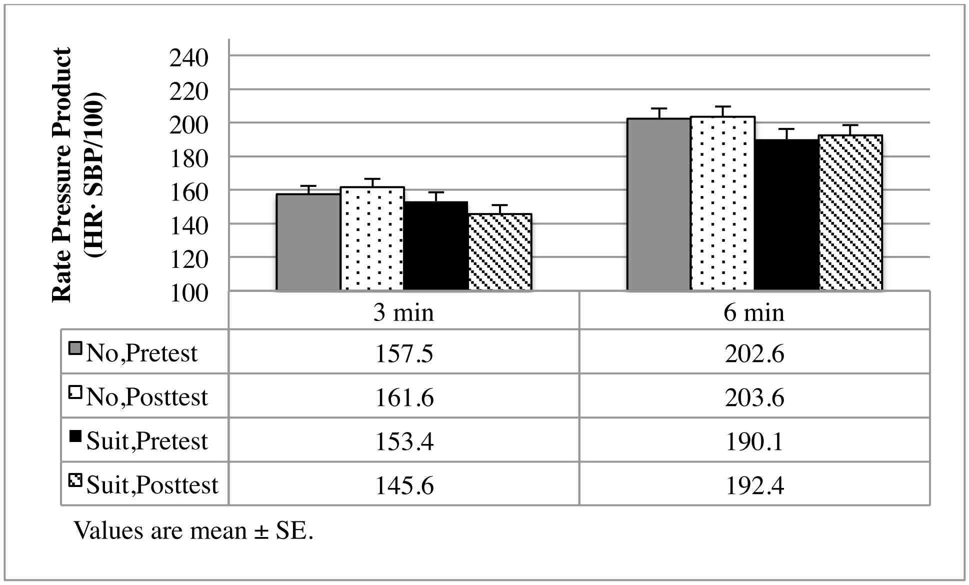
	3 min	6 min	9 min	12 min	15 min
▦ No,Pretest	112	130.5	163	184.2	193
□ No,Posttest	117.5	136	158.5	181.5	194
■ Suit,Pretest	102	123	152.6	186.3	197.3
▨ Suit,Posttest	99.5	116.7	147.7	181.2	195.2

Values are mean ± SE.

Figure 14. Mean Heart Rate Comparisons at Submaximal Work Rates for Pre- and Post-maximal Graded Exercise Testing.

Rate Pressure Product

The changes in rate pressure products were determined by comparing these values between 3 and 6 minutes of the pre- and post-maximal graded exercise tests by group (with or without the exercise suit), test (pre and post), and test interacted with group. The results from the two by four ANOVA indicate that there was no difference between rate pressure products for group, test, and group interacted with test ($P > 0.01$). The means for rate pressure product for these conditions are displayed in Figure 15.



	3 min	6 min
▣ No,Pretest	157.5	202.6
□ No,Posttest	161.6	203.6
■ Suit,Pretest	153.4	190.1
▨ Suit,Posttest	145.6	192.4

Values are mean ± SE.

Figure 15. Mean Rate Pressure Product Comparisons at Submaximal Work Rates for Pre- and Post-maximal Graded Exercise Testing.

Body Composition Change

It was hypothesized that wearing the exercise suit during the exercise intervention would result in more favorable changes in body composition compared to not wearing the exercise suit because it was assumed that training with the exercise suit would result in greater energy demands. The results indicate that there was no difference for the change in lean mass with or without the exercise suit between the 6-week intervention ($P > 0.01$). The mean lean mass change with the exercise suit was + 0.13 kg [-0.85, 1.12] and – 0.10 kg [-0.99, 0.79] without the suit. There was no difference in the change of body fat mass with or without the exercise suit ($P > 0.01$). The mean fat mass change with the exercise suit was -0.85 kg [-1.85, 0.15] and -0.27 kg [-1.17, 0.64] without the suit. There was no difference in the change of total % body fat with or without the exercise suit. The mean total % body fat change with the exercise suit was – 0.94 % [-1.92, 0.03] and – 0.27 % [-1.159, 0.61] without the suit. There was no difference in weight change with or without the exercise suit ($P > 0.01$). The mean weight change between the exercise intervention with the exercise suit was – 0.32 kg [-1.61, 0.96] and – 0.24 kg [-1.461, 0.98] without the suit. The multivariate regression analysis for changes in lean mass ($R^2 = 0.03$) fat mass ($R^2 = 0.11$) and total percentage body fat (% fat) ($R^2 = 0.15$) were both statistically non-significant ($P > 0.01$). The results of body composition changes are reported in Table 3.

Bone Mineral Density Change

The changes in bone mineral density before and after the 6-week exercise intervention for both groups were statistically non-significant ($P > 0.05$) and align with the null hypothesis that there will be no differences between bone mineral densities between the groups. The mean change with the exercise suit was – 0.00611 $g \cdot cm^{-2}$ [-0.019, 0.006] and – 0.00618 $g \cdot cm^{-2}$ [-0.015, 0.003] without the suit. The bone mineral density change is reported in Table 3.

Leg Strength Change

It was hypothesized that training with the exercise suit would result in greater changes in leg strength compared to without the suit. The changes in leg strength as measured by a 1-RM leg press were non-significant ($P > 0.05$). The mean change without the exercise suit was + 6.2 kg [-14.1, 26.5] and – 14.77 kg [-36.05, 6.5] with the exercise suit. This finding might be due to the participants' lack of desire to achieve maximal effort. The change in leg strength is reported in Table 3.

Treadmill Time to Exhaustion Change

It was hypothesized that exercise training outcome with the exercise suit would result in longer treadmill times to exhaustion compared to without the suit. The mean change was with the exercise suit was + 47.8 s [9.35, 86.25] and + 73.63 s [36.97, 110.3] without the exercise suit. Both groups demonstrated longer treadmill times to exhaustion, however the participants who exercised without the suit had greater endurance, but this difference was not statistically significant ($P > 0.05$).

Discussion

This section will ascribe several possibilities which may have resulted in the null findings for the effect of the exercise suit on maximal graded exercise testing, variables measured during the exercise intervention, and the differences in the changes between the exercise intervention. Among these explanations will be many future research considerations examining the effect of the exercise suit on selected variables of interest.

Maximal Graded Exercise Testing with the Exercise Suit

One objective of this study was to determine the physiological effects of the exercise suit during a maximal graded exercise test compared to a control condition using the Bruce protocol (Kaminsky & Whaley, 1998). The results indicate that there was no difference for any physiological measure between the maximal graded exercise tests with or without the exercise suit at any given submaximal exercise stage. Factors such the testing design, sample size, and test accuracy could be attributed to these non-significant findings.

Maximal graded exercise testing to $\dot{V}O_{2\max}$ with and without the exercise suit was a test-retest design. For this design, all participants completed the $\dot{V}O_{2\max}$ tests without the exercise suit before $\dot{V}O_{2\max}$ testing with the exercise suit. These tests were separated by a 1-week washout period. $\dot{V}O_{2\max}$ testing with and without the exercise suit should have been counterbalanced to control for learning effects. The order in which participants completed the $\dot{V}O_{2\max}$ tests with or without the suit should have been randomized to account for any testing effects or behavior learned from the initial testing condition. Controlling for these factors would have reflected the effect of the exercise suit on maximal graded exercise testing to $\dot{V}O_{2\max}$ better than the design used.

It has been well established that $\dot{V}O_2$ is directly proportional to the intensity of exercise. Oxygen consumption increases as exercise intensity increases (Brooks, Fahey & Baldwin 2005, p. 343). It is also known that exercising with additional weight or loads carried externally can result in greater oxygen demand. For maximal graded exercise testing to $\dot{V}O_{2\max}$, oxygen uptake should have been greater across each submaximal exercise stage with the exercise suit because the exercise suit added 5.45 kg to the participants' weights during testing. The data obtained from this test should have highlighted this response but the design was not counterbalanced.

Furthermore, there were non-significant differences for heart rates and blood pressures between maximal graded exercise testing with and without the exercise suit, which could have been attributed to the test-retest design. It has been established that heart rates increase in proportion to exercise intensity. Systolic blood pressures increase in proportion to exercise intensity while relatively little change occurs for diastolic blood pressures given the exercise intensity level. Heart rates and blood pressures should have been greater across each submaximal exercise stage because the weight of the exercise suit should have induced greater physiological responses among the participants. In addition, it was evident that there could have been learning or testing effects between the testing conditions because heart rates were significantly higher for the first $\dot{V}O_{2\max}$ test without the exercise suit at the first submaximal exercise stage compared to the second $\dot{V}O_{2max}$ test with the exercise suit. This finding may suggest that the participants could have learned and adapted physiologically to the first $\dot{V}O_{2max}$ test without the exercise suit.

The null findings from submaximal oxygen consumption rates to maximal graded exercise testing resulted in non-significant differences for respiratory exchange ratios with and without the exercise suit. Respiratory exchange ratios were measured using indirect calorimetry as the rate of carbon dioxide produced to the rate of oxygen consumed which can be used to estimate fatty acid and carbohydrate fuel contribution to exercise. It should be noted that the use of indirect calorimetry was limited to the respiratory gases consumed and produced at the mouth and does not take protein degradation into consideration for energy utilization during exercise (Brooks, Fahey & Baldwin, 2005, p. 51). RER values equal to 0.7 indicate fatty acid metabolism while values equal to 1.0 indicate carbohydrate metabolism. RER values between 0.7 and 1.0 indicate a combination of fatty acid and carbohydrate metabolism (Brooks, Fahey & Baldwin, 2005, p. 49). The shift from fatty acid to carbohydrate metabolism can be attributed to increased exercise intensity during strenuous exercise but varies due to individual differences, which can be attributed to skeletal muscle fiber type proportions, mitochondrial size and number, and capillary densities.

Respiratory exchange ratios should have been greater with the exercise suit across all submaximal exercise stages compared to without the exercise suit for maximal graded exercise testing to $\dot{V}O_{2max}$. The added weight of the exercise suit should have initiated the shift from fatty acid to carbohydrate metabolism at lower intensities across submaximal exercise stages compared to without the exercise suit. This would be a result in a greater proportion of carbon dioxide production to oxygen consumption, which would have resulted in greater ratings of perceived exertion and faster fatigue times due to reaching anaerobic threshold at lower intensities. However, the results indicate that there was no difference for ratings of perceived exertion and treadmill times to exhaustion with or without the exercise suit.

Tympanic membrane temperature was also measured during maximal graded exercise testing to exhaustion with and without the exercise suit. These temperatures were measured because the exercise suit covered the participant's entire body, which could interfere with the body's ability to thermoregulate. The results indicate that there was no difference for tympanic membrane temperatures at any given submaximal exercise stage with or without the exercise suit. This non-significant finding could be attributed to that temperatures were limited to the tympanic membrane. Temperatures at this location were used to estimate core temperature. Perhaps measuring core temperature directly using a rectal thermistor or an ingestible temperature sensor could have been more valid for identifying core temperature differences across submaximal exercise stages with or without the exercise suit. Future research should strongly consider this method if indeed there was an effect of the exercise suit on the body's ability to regulate core temperature.

Future studies examining oxygen uptake, heart rates, blood pressures, respiratory exchange ratios, ratings of perceived exertion, treadmill times to exhaustion, and temperature for maximal graded exercise testing with the exercise suit should strongly consider a counterbalanced design and using a rectal thermistor or ingestible temperature sensor for determining core temperature. This would help identify any differences for these variables across submaximal exercise stages compared to a control condition without the exercise suit.

In addition to these considerations, a greater sample size for this test is also strongly recommended. Future studies should have a larger sample size to allow for greater statistical power and the ability to make an inference on the effect of the exercise suit on maximal graded exercise testing to exhaustion. A power analysis was conducted to determine the least significant number needed to achieve statistical significance ($P < 0.05$) using the same variance of the error and the effect size of the original data for the effect of the exercise suit on $\dot{V}O_2$ across submaximal exercise stages. The results from this analysis indicated that 720 total observations were needed to achieve statistical significance for the effect of the exercise suit on $\dot{V}O_2$ during maximal graded exercise testing. Future research examining $\dot{V}O_2$ should strongly consider meeting the least significant number needed for statistical significance if there truly is an effect of the exercise suit on $\dot{V}O_2$.

During maximal graded exercise testing to $\dot{V}O_{2max}$ with and without the exercise suit, the TrueOne 2400 metabolic measurement system was faulty and inconsistent for determining oxygen uptake values. For instance, values for oxygen uptake during the early stages of submaximal testing appeared to be accurate but then spontaneously fell out of normal range as the participant completed the later submaximal exercise stages. These values were either extremely high or low, which affected other variables like respiratory exchange ratios. At this time it was noticed that the mixing chamber was highly saturated with moisture from the expired gases produced by the participants. The moisture could have penetrated the internal mechanisms of the metabolic measurement system and produced bad data. During initial testing, it was thought that filters attached to the pneumotachometer could be used more than once for maximal graded exercise testing, which was later determined to be inaccurate. From this finding, it was determined that used filters should be replaced with a new, dry filter for every maximal graded exercise test to $\dot{V}O_{2\max}$. This will result in greater gas analysis accuracy from the TrueOne 2400 metabolic measurement system and limit the amount of moisture that the pneumotachometer comes into contact with. This procedure was implemented for the post- $\dot{V}O_{2\max}$ tests after the 6-week exercise intervention.

Moreover, there were no contraindications to exercise for the initial maximal graded exercise testing to $\dot{V}O_{2\max}$ with the exercise suit. All participants were able to achieve $\dot{V}O_{2\max}$ without any adverse physiological responses to exercise and were able to move freely in the exercise suit without any complications. Some participants noted that, “I was hot” or “that was harder” compared to maximal graded exercise testing without the exercise suit. Other participants claimed that they were confident in their ability to perform aerobic exercise with the exercise suit. Given these findings, initial pilot work, and interactions with the participants, the researcher was assured that the exercise suit was safe to wear during the 6-week aerobic exercise intervention under controlled conditions.

Exercise Intervention Outcomes

The results from the 6-week exercise intervention indicate that there was no difference between exercise sessions and across the 6-weeks with or without the exercise suit for weight changes, exercise systolic blood pressures changes, exercise diastolic blood pressure changes, and exercise tympanic membrane temperature changes. It should be noted that the previously sedentary male participants were limited to 40 minutes (5 min warm-up, 30 minute aerobic training, 5 minute cool-down) of aerobic exercise at 60%-70% of their maximum heart rate determined by their initial $\dot{V}O_{2\max}$ test without the suit for 3 nonconsecutive days each week, lasting 6-weeks with or without the exercise suit. Several explanations for these results will be discussed given this limitation alongside participant's individual differences and previous physical activity history.

Benefits of progressive aerobic exercise are improvements in cardiovascular and respiratory function, however the effect of aerobic exercise using a weighted exercise suit on weight change, blood pressure changes, and tympanic membrane changes is unclear. For this study, weight change was determined by the differences in weight before and after the exercise session. Blood pressure (systolic and diastolic), and tympanic membrane temperature changes were the differences at rest and at the middle (20 minutes) of the aerobic training session. These changes were analyzed for the average change per exercise session each week and then compared across the 6-weeks.

Garrow & Summerbell (1995) asserted in a meta-analysis composed of studies examining body composition changes among sedentary men and women engaged in an exercise program designed to promote fat loss that aerobic exercise, "causes a modest loss in weight without dieting." The results from this study demonstrated that there was no difference in weight change for participants aerobically exercising with or without the exercise suit for exercise sessions and across the 6-weeks. Given this finding in relation to previous research, it is unclear if the exercise suit could have an effect on weight changes after progressive aerobic exercise.

The non-significant weight changes observed for this study could be attributed to the length of the exercise intervention, which was only 6-weeks. It could be possible that this exercise intervention was not long enough to determine a significant weight change between the participants exercising with or without the exercise suit. Fogelholm and Kukkonen-Harjula (2000) conducted a meta-analysis on several studies between the years 1980 and 2000 that examined weight changes from physical activity interventions among white, sedentary adults. When the results were analyzed, it appeared that the studies utilizing a randomized control weight reduction intervention were greater than 6 weeks. Of these studies finding significant weight reductions within the intervention group, the intervention length range was 8-weeks (Pavlou, Krey & Steffee, 1989) to 1-year (Skender, Goodrick, Del Junco, Reeves, Darnell, Gotto & Foreyt, 1996). It could be possible that the effect of the exercise suit on weight change could be apparent if the aerobic exercise intervention was greater than 6-weeks.

Perhaps the intensity and frequency of the aerobic exercise session across the 6-week intervention were not high enough to elicit a significant weight change with or without the exercise suit as well. Participants were limited to jogging at 60%-70% of their maximum heart rate during the exercise intervention. Perhaps the effect of the exercise suit on weight change could be possible at greater submaximal heart rate ranges. This might have an effect on the exercise energy demands, which over time might have a benefit for weight loss or maintenance.

The frequency, intensity, and duration of the aerobic exercise intervention also resulted in non-significant changes for blood pressures and tympanic membrane temperatures during exercise. It is possible that if this study were extended to more than

6 weeks or adjusted to higher exercise intensities, then there could be more noticeable changes for these variables. It is possible that the physiological adaptations to the aerobic exercise intervention with the exercise suit could have occurred if this study were extended past the 6-weeks. Moreover, the non-significant changes could also be attributed to the participants' initial physical characteristics.

The male participants were previously sedentary, at "low-risk" for cardiovascular disease, and had not participated in a physical activity or exercise program within the last month. Given these inclusion criteria for participation into this study, the results indicate that the participants were relatively healthy and in moderate physical condition beforehand. The average age, BMI, $\dot{V}O_{2max}$, and leg strength for participants before the exercise intervention was 20 years, 25 $kg \cdot m^{-2}$, 49.5 $mlO_2 \cdot kg^{-1} \cdot min^{-1}$, and 146.2 kg respectively. It could be said that the frequency, intensity, and duration of the aerobic exercise intervention was not sufficient enough to stimulate weight, blood pressure, or tympanic membrane temperature changes among the participants. It is also a possibility that the exercise intervention may have also resulted in training retrogression or plateau. It is conceivable that older, deconditioned participants could demonstrate significant improvements in in weight, blood pressure, and tympanic membrane temperature changes across the exercise intervention. Future, studies examining the effect of the exercise suit on these variables should consider redefining the inclusion criteria in favor for obese, deconditioned participants of similar or older ages.

Exercise Training Outcomes

The results indicate that there was no difference between the changes in weight, blood pressures, or tympanic membrane temperatures across the 6-week exercise intervention with or without the exercise suit. Possible explanations for these null results were the frequency, intensity, and duration of the exercise intervention and limited sample size. It is highly suggested that future research examining the effect of the exercise suit on physiological changes should consider adjusting the exercise prescription for future intervention studies and obtain larger sample sizes for greater statistical power. The outcome of this study's exercise intervention resulted in non-significant changes for $\dot{V}O_{2max}$, body composition, bone mineral density and leg strength. Factors that may have contributed to these non-significant findings such as the intervention design, participant individual differences, equipment accuracy, and limited sample size will be discussed in this section.

One of the primary hypotheses of this study was that training with the exercise suit would result in greater changes in $\dot{V}O_{2max}$ because the weight exercise suit should have caused greater physiological responses and adaptations to exercise. The results indicate that there was no difference for the change in $\dot{V}O_{2max}$ with or without the exercise suit between the exercise intervention. This result also attributed to a non-significant difference for treadmill time to exhaustion. We can ascribe possibilities to explain these results.

Exercise prescription is an important moderator for exercise training outcomes. Training frequency, intensity, time and type of exercise should reflect the purpose of the training program, which in this study was to increase $\dot{V}O_{2max}$ among previously sedentary college-aged males. Participants were limited to 40-minutes of "moderate" aerobic exercise three times a week for six weeks. This exercise prescription resulted in slightly greater nonsignificant changes in $\dot{V}O_{2\max}$, however it could be possible that the frequency, intensity, and time of aerobic exercise was not sufficient to stimulate significant changes between the groups. This study maintained the exercise prescription throughout the six weeks, which might have been better for other subpopulations. Perhaps adjusting the intensity level in between the intervention period could initiate greater training effects. For instance, exercise intervention weeks 1-3 could be exercising at 60%-70% of maximum heart rate and then readjusted to 65%-75% of maximum heart rates for weeks 4-6. If the study was extended to more than 6-weeks, then progressive intensity could be implemented in weekly blocks to maximize training effects. This intervention design could be beneficial for participants who are healthy and in moderate to good physical condition. The researcher should strongly consider aligning the exercise prescription to the initial training status of their population of interest to amplify the effect of the exercise suit on selected physiological variables.

It is also possible that some participants did not put forth maximum effort on the post maximal graded exercise test. This may have explained the lack of a treatment effect from the exercise suit, which resulted in no $\dot{V}O_{2\max}$ or treadmill time to exhaustion changes. Participants' psychological statuses could have also influenced their effort level during maximal graded exercise testing to exhaustion. Participants could have experienced "burnout" from the exercise intervention or could have had outside stressors like academic obligations, which could have affected their performance on the final $\dot{V}O_{2\max}$ test. Future research should consider methods to augment participant effort levels in order to determine a noticeable effect of the treatment.

A limited sample size could have also contributed to the null change in $\dot{V}O_{2\max}$. There were a total of 17 observations used to determine the change in $\dot{V}O_{2\max}$ using 6 explanatory variables in the multivariate regression analysis. The p-value for the effect of the exercise suit on the change in $\dot{V}O_{2\max}$ was weak ($P = 0.41$) while initial lean mass was strong but non-significant ($P = 0.055$). A power analysis was used to determine the least significant number needed to observe a statistically significant ($P < 0.01$) change in $\dot{V}O_{2\max}$ using the same variance and effect size of the original data. It was determined that 158 total observations were needed for a statistically significant effect of the exercise suit on $\dot{V}O_{2\max}$ change with an 'a priori level of significance $P < 0.01$. Furthermore, equipment malfunctions with the TrueOne 2400 metabolic measurement system occurred during post- $\dot{V}O_{2\max}$ testing which limited the amount of data that were used for the previous analysis. Filters on the pneumotachometer were replaced with new, dry filters for every post- $\dot{V}O_{2\max}$ test but there were still tests that were inaccurate because of repeated testing. Future studies examining the effect of the exercise suit on $\dot{V}O_{2\max}$ change should strongly consider a large sample size in order to achieve statistical significance and account for equipment malfunctioning during repeated maximal graded exercise testing.

The effect of the exercise suit on the change in body composition was non-significant as well. Participants were in relatively good physical condition before the onset of the exercise intervention, which could possibly explain why there were no changes in body composition after. Perhaps the effect of the exercise suit on body composition change would be more favorable for another subpopulation such as overweight or obese, deconditioned individuals. It could also be possible that the weight of the exercise suit was not sufficient enough to stimulate a significant change in body composition among this study's participants. Maybe the exercise suit could initiate body composition change if it weighed more, which might influence the energy costs associated with exercise or physical activity.

Moreover, there was no difference for the change in bone mineral density with or without the exercise suit. Plowman and Smith (2013) assert that age and sex influence bone health. This study was limited to males with a mean age of 20 ± 3 years. Beck and Marcus (1999) stated that "…95% of peak bone mass is achieved by age 20." The average total bone mineral density for all participants was 1.25 ± 0.14 $g{\cdot}cm^{-2}$, which exceeds the age adjusted (> 20 years) mean total bone mineral density values for males of all races and ethnicities during 1999-2006 (Looker, Borrud, Hughes et al., 2013. p. 11). It could be said that participants had reached their peak total bone mineral density before the onset of this study, which resulted in no change between the groups.

Moreover, exercise has been suggested to be a unique modality for maintaining bone mineral density for younger and older adults (Snow-Harter & Marcus, 1991). Maybe the effect of the exercise suit on bone mineral density could be examined among other subpopulations that are at risk for low bone mineral density disorders such as osteopenia or osteoporosis. This population may show more noticeable bone mineral density changes if the exercise suit were worn during physical activity or exercise because the exercise suit adds 5.45 kg to the individual's weight. However, it is not clear how the exercise suit affects bone mineral density after aerobic exercise training because the results for this change were non-significant.

It was also not clear as to whether the exercise suit could improve leg strength. The results indicate that there was no difference for change in leg strength with or without the exercise suit between the exercise intervention. One possible explanation to this observation could be the participants' individual differences pertaining to body composition or the participant's effort level on the post leg strength test. Ratings of perceived exertion for the 1-repetition maximal leg strength tests were not recorded for this study. Therefore effort levels could not be quantified and compared between the groups.

The specificity of muscle fiber type conversion and adaptation is highly dependent on individual differences and the type of exercise. These factors could also explain the changes in leg strength that occurred between the groups. Some participants could have had varied training responses and adaptations to the aerobic exercise intervention with or without the exercise suit due to dietary intake, hormonal balance, or psychosocial factors. Moreover, skeletal muscle adaptations to progressive aerobic exercise are different compared to progressive resistance exercise. Each training type gives implications to strength outcomes, which in this study was measured by a 1-repetition maximal leg press. Brooks, Fahey, and Baldwin (2005) stated that aerobic training does not lead to increases in muscle cross-sectional areas but rather increases the metabolic activity within the muscle cell (p. 437). Resistance training results in muscle hypertrophy, which can lead to greater cross-sectional areas of muscles and greater muscle motor recruitment (p. 438). This study's intervention was specific to aerobic exercise and should have stimulated more type I fibers during exercise. It is plausible that the aerobic exercise intervention stimulated more type I muscle fiber recruitment and development compared to type II muscle fibers. This may have attributed to the null changes in leg strength. Future studies examining the effect of the exercise suit on leg strength in relation to body composition could consider muscle biopsies to determine muscle fiber type conversion and metabolic activity.

The results for this study were predominantly centered on the effect of the exercise suit on “moderate” aerobic exercise. It is possible that the results for this study could have been different if it controlled for nutrition. It is well known that certain types of food can strongly influence training performance, adaptations, and body composition from exercise or physical activity. It has been established that the proportion of lean to fat mass are directly associated to $\dot{V}O_{2\max}$ (Chatterjee, S., Chatterjee, P. & Bandhopadhyay, 2005; Welch, Riendeau, Crisp & Isenstein, 1958). Greater proportions of lean mass to fat mass are associated with higher $\dot{V}O_{2\max}$ capacities and vice versa. The differences between “high fat” and “low fat” diets could be the determining factors for the effect of the exercise suit on body composition change and $\dot{V}O_{2\max}$. The nutritional interactions with exercise or exercise with the exercise suit could influence training adaptations, body composition and $\dot{V}O_{2\max}$ change, which may result in noticeable changes for body composition and $\dot{V}O_{2\max}$. Future studies should strongly consider implementing a dietary journal or a nutritional assessment to account for the effects of the exercise suit on the associated changes in selected variables.

This study accounted for the effect of the exercise suit on dehydration by taking weight measurements before and after the exercise sessions. Dehydration was examined because the exercise suit was full-bodied in design, which created a thermal barrier between the participants' skin and external environment. This could have affected the body's ability to dissipate heat and the mechanisms that regulate body temperature. The results indicate that there was no difference between the changes in weight with or without the exercise suit. However, this study did not control for water consumption during the exercise intervention, which may have influenced the physiological responses from exercise. Future studies examining the effect of the exercise suit on dehydration should consider a criterion for water consumption during exercise to better measure the effect of the exercise suit on this response.

This discussion highlighted several considerations for future studies examining the effect of the exercise suit on $\dot{V}O_{2max}$, temperature, body composition, bone mineral density and leg strength. In future research to investigate the effect of the exercise suit on selected variables it is strongly recommended to design studies that reflect the intended purpose of the research question and account for inevitable equipment discrepancies during testing. The sample size for this study limited the statistical power and ability to draw conclusions on the effect of the exercise suit on maximal graded exercise testing to $\dot{V}O_{2max}$, and the changes in the aforementioned variables. Power analyses were conducted for the least significant number needed for statistical significance on the effect of the exercise suit using the same variance and effect size of the original data, which were provided in this discussion. In addition, the effect of the exercise suit should be studied among different subpopulations. These populations might show more noticeable effects from training with the exercise suit given that a large sample size was used for statistical analysis.

Chapter 5

Summary, Findings, Conclusion and Recommendations

Summary

The purpose of this study was to investigate the effects of wearing a uniformly-weighted, full-bodied exercise training suit on $\dot{V}O_{2max}$, blood pressure, heart rate, rating of perceived exertion (RPE), tympanic membrane temperature, body composition, bone mineral density, and leg strength during a 6-week aerobic training intervention among previously sedentary males. Previous research has been centered on the effects of weighted personal protective equipment among active military personnel or localized weighted load carriage systems or vests among young and older adults on performance and biomechanical outcomes. Little research has been done to explore the effects of a moderately-weighted load carriage system under controlled training conditions among sedentary young adults. This study endeavored to test the effects of an innovative exercise training suit developed by Athlotek, L. L. C., on maximal cardiorespiratory fitness, body composition, and leg strength during a moderate aerobic training program.

Twenty-one previously sedentary, “low-risk,” college-aged males were recruited, screened, and matched for $\dot{V}O_{2max}$, height, weight, and leg strength before being randomly allocated into a 6-week aerobic exercise intervention with or without the exercise suit. Before the exercise intervention, an additional $\dot{V}O_{2max}$ test was performed with the exercise suit in order to determine the physiological effects in comparison to the $\dot{V}O_{2max}$ without the exercise suit. The aerobic exercise intervention training sessions consisted of 40-minutes on a treadmill (5 min warm-up, 30 min aerobic training, and 5 min cool-down) with participants jogging at 60%-70% of their maximum heart rate determined by the first $\dot{V}O_{2max}$ test without the suit for 3 nonconsecutive days each week, lasting 6-weeks with or without the exercise suit. Weight was recorded before and after each session while blood pressures and tympanic membrane temperatures were recorded before, during, and after each session throughout the 6-weeks. Heart rate was monitored continuously using digital telemetry for each session to confirm that participants were within their determined heart rate range for aerobic training. Upon completion of the intervention, participants performed a set of posttests consisting of a $\dot{V}O_{2max}$ test without the exercise suit, body composition analysis, and a 1-repetition maximal leg press, which were compared to the initial pretests.

Findings

1. There were no differences between $\dot{V}O_2$ uptake at any given submaximal exercise stage during maximal graded exercise testing with or without the exercise suit.
2. There were no differences between respiratory exchange ratios at any given submaximal exercise stage during maximal graded exercise testing with or without the exercise suit.
3. There were no differences between systolic and diastolic blood pressures at any given submaximal exercise stage during maximal graded exercise testing with or without the exercise suit.
4. There were no differences between Ratings of Perceived Exertion scores at any given submaximal exercise stage during maximal graded exercise testing with or without the exercise suit.
5. Heart rate with the exercise suit was significantly lower at the first submaximal exercise stage during maximal graded exercise testing compared to without the exercise

suit ($P < 0.05$). There were no differences between heart rates at any further submaximal exercise stage during maximal graded exercise testing with or without the exercise suit.

6. There were no differences between tympanic membrane temperatures during any given submaximal exercise stage during maximal graded exercise testing with or without the exercise suit.
7. There were no differences between treadmill times to exhaustion during maximal graded exercise testing with or without the exercise suit.
8. There were no differences between $\dot{V}O_{2max}$ change with or without the exercise suit.
9. There were no differences between lean mass change with or without the exercise suit.
10. There were no differences between fat mass change with or without the exercise suit.
11. There were no differences between total body percentage fat (% fat) change with or without the exercise suit.
12. There were no differences between weight change with or without the exercise suit.
13. There were no differences between bone mineral density change with or without the exercise suit.
14. There were no differences between leg strength change with or without the exercise suit.
15. There were no differences between treadmill time change to exhaustion with or without the exercise suit.

Conclusion

The results of this study indicate that there were no differences between maximal graded exercise testing, change in $\dot{V}O_{2max}$, change in body composition, change in bone mineral density, and change in leg strength with or without the exercise suit.

These findings suggest that there was no benefit to wearing the exercise suit compared to a control condition – without the exercise suit. However, it appears that the exercise suit is safe and could be used for training purposes under controlled conditions.

Recommendations

1. Obtaining a greater sample size may result in more statistical significance on chosen performance variables. Necessary sample size can be achieved by performing a power analysis using similar studies having relatable research questions. Future research should strongly consider the least significant numbers calculated from the power analyses used in this study for the change in $\dot{V}O_{2\max}$ and blood pressures.
2. Future research should strongly consider designing the study to fit the intended purpose of the research question. Techniques such as counterbalancing, matching, randomizing, and treatment blocks help control for confounding variables and magnify the treatment effect.
3. The researcher(s) should have a solid foundation for the inclusion and exclusion criteria into their study. Controlling for the variance between participants will help eliminate confounding factors that may contribute to an inaccurate reflection of the results.
4. Future research should examine the effects of subsequent exercise treatments in order to determine the changes in performance and body composition among different age and gender populations. The frequency, intensity, time, type, and duration of the exercise treatment with the exercise suit could result in more distinct changes in exercise performance and body composition. Moreover, women or older adults from different subpopulations could also participate in a similar study using the exercise suit.

These populations might yield interesting changes in performance, body composition, and bone mineral density.

5. Leg strength measurements should be obtained using a leg press “sled” or by performing a squat exercise. The sled machine allows for the participant to add or remove circular weights with no weight limitation. A squat exercise could also measure lower body strength but has far more safety considerations compared to a leg press machine. For safety purposes, this study used a leg press machine where participants were seated in an upright position and used a steel dowel to adjust the weight.

6. The researcher(s) should expect equipment malfunctions and be ready to calibrate or fix any equipment deformations, which might result in errors within the data. Moreover, the researcher should do extensive pilot testing in order to become familiar with all equipment that will be used in their study, especially for the TrueOne metabolic cart. It was determined that the filter on the pneumotachometer should be replaced with a clean and dry filter for every VO_{2max} test in order to maintain the integrity of the data during these tests. If the filter on the pneumotachometer is not replaced after each consecutive exercise test, excess saliva or moisture can penetrate into the pneumotachomter and eventually into the inner workings of the gas analyzer. The analyzer will misinterpret the gas content due to the excess moisture.

7. Future designs of the exercise suit should be tailored to fit the special needs of individuals of different age, sex, and body composition. In addition, the next generations of the exercise suits should feature designs that promote better air flow within the suit, which will help with heat dissipation. Additional zippers, fabric modifications, and different exercise suit sizes might help with this process. Moreover, modifying the

weight of the exercise suit might also be beneficial for individuals with different training histories. Light, moderate, and heavy exercise suits could be made in order to accommodate those with different training regimens.

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Appendix A

Informed Consent

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT, "The Impact of a Novel Exercise Training Suit on Cardiorespiratory Fitness"

A research project on cardiorespiratory fitness is being conducted by Trevor Curry, Dr. Steve Davis and Don Clegg M.S., from the Department of Kinesiology at Cal Poly, San Luis Obispo. Dr. Aydin Nazmi from the Department of Nutrition at Cal Poly and Lawrence Petrakis, M.D., FRCP(C) FRSM, of Saint Francis Memorial. The purpose of this study is to investigate the training effects of a novel exercise training suit on cardiorespiratory fitness.

You are being asked to take part in this study by completing 6-weeks of exercise training (jogging) in the Human Performance Lab of the Kinesiology Building (43A-250) and Recreation Center on the Cal Poly Campus. 1-week before and after the training period, you will be completing a series of pretests and posttests involving weight classification (BMI), body composition (Dual Energy X-ray Absorptiometry and hydrostatic weighing), cardiorespiratory fitness (VO_{2max}), and 1-repetition maximal strength test using a leg press machine. You will also complete one additional VO_{2max} test with the exercise suit during the pretest but not the posttest. After the series of pretests, you will be placed in one of two groups with or without the exercise suit.

The exercise training suit is uniformly weighted in the form of a thin and flexible fabric and worn over a person's whole body. You will be aerobically training on a treadmill 3 times per week on nonconsecutive days either wearing shorts and a t-shirt plus the exercise suit, or in shorts and t-shirt without the exercise suit. These training sessions will be approximately 40 minutes in duration and will consist of approximately a 5-minute warm-up, 30-minute training period at 60-70% of your maximal heart rate, and a 5-minute cool-down period. You will have the opportunity to schedule your exercise sessions accordingly. The expected total amount of time required to participate in this study is approximately 14 hours. Please be aware that you are not required to participate in this research and you may discontinue your participation at any time without penalty. You will be rewarded with a $5 gift card each week if you complete all 3 sessions of that week for six weeks (total of $30).

The possible risks associated with participation in this study include physical and psychological risks. Physical risks include: falling, pain, discomfort, muscle soreness, injury, dizziness, dehydration, hunger, headache, tingling, hyperthermia, weight loss, and in rare cases, nausea, vomiting, or heart-attack. Psychological risks include: emotional distress, sadness, embarrassment, decreased self-esteem, and/or decreased self-confidence. Social risks include: feelings of pressure or inadequacy; fear of not performing to appropriate level; anxiety associated with performing in front of an experimenter. If you should experience any of the negative physical, emotional, or social outcomes as described above, please be aware that you may contact the Cal Poly Health and Counseling Services at (805)756-2511 or Trevor Curry at (916)207-9876 for assistance. There will be two certified CPR test administrators present during your assessments and exercise sessions.

Your confidentiality will be protected by removing any questionnaire face sheets containing identifying information; code numbers will be used in place of names; the individuals with access to data containing identifiers will be limited to the researchers identified on this form; data will be stored in locked cabinets and password protected devices. Potential benefits associated with the study include acute physical and psychological outcomes. Physical benefits may involve increased muscle strength, endurance, and metabolism. Psychological benefits may involve increased confidence, motivation, satisfaction, and heightened social interaction. Furthermore, you will be testing new exercise technology that has potential to enhance the benefits associated with physical activity and/or exercise. Participating in this study will allow the researchers to receive a better understanding of how the exercise suit influences one's cardiorespiratory fitness level.

If you have questions regarding this study or would like to be informed of the results when the study is completed, please feel free to contact Trevor Curry at (916) 207-9876 or trcurry@calpoly.edu. You may also contact Dr. Aydin Nazmi at (805) 756-6447 or nazmi@calpoly.edu. If you have questions or concerns regarding the manner in which the study is conducted, you may Dr. Dean Wendt, Dean of Research, at (805) 756-1508, dwendt@calpoly.edu.

If you agree to voluntarily participate in this research project as described, please indicate your agreement by signing below. Please indicate if you agree to have your picture taken during exercise sessions for research purposes by signing below. These pictures will be displayed for the exercise suit manufacturer and poster board presentations. Lastly, please keep one copy of this form for your reference, and thank you for your participation in this research.

________________________________ Signature of Volunteer   _______________ Date

________________________________ Signature of Researcher   _______________ Date

I agree to have my picture taken   Yes____   No____

Appendix B

Canadian Society for Exercise Physiology's PAR-Q and YOU Health History Questionnaire

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	**1.**	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2.**	**Do you feel pain in your chest when you do physical activity?**
☐	☐	**3.**	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4.**	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5.**	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6.**	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7.**	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

→

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ______________________________

SIGNATURE OF PARENT ____ WITNESS ______________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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Appendix C

Medical History Questionnaire

Participant:

Name ____

Address ____

Contact phone numbers __________________________________

Birth date ____

Sex:

☐ Male ☐ Female

Occupation:

Position ____

What is (are) your purpose (s) for participation in this Fitness Program?

- ☐ To determine my current level of physical fitness and to receive recommendations for an exercise program.
- ☐ Other (please explain) ____

____

____

____

____

Present Medical History

Check those questions to which you answer yes (leave the others blank).

- ☐ Has a doctor ever said your blood pressure was too high?
- ☐ Do you ever have pain in your chest or heart?
- ☐ Are you often bothered by a thumping of the heart?
- ☐ Does your heart often race?
- ☐ Do you ever notice extra heartbeats or skipped beats?
- ☐ Are your ankles often badly swollen?
- ☐ Do cold hands or feet trouble you even in hot weather?
- ☐ Has a doctor ever said that you have or have had heart trouble, an abnormal electrocardiogram (ECG or EKG), heart attack or coronary?
- ☐ Do you suffer from frequent cramps in your legs?
- ☐ Do you often have difficulty breathing?
- ☐ Do you get out of breath long before anyone else?
- ☐ Do you sometimes get out of breath when sitting still or sleeping?
- ☐ Has a doctor ever told you your cholesterol level was high?
- ☐ **Has a doctor ever told you that you have an abdominal aortic aneurysm?**
- ☐ **Has a doctor ever told you that you have critical aortic stenosis?**

Comments: ______________________________

____

____

____

Do you now have or have you recently experienced:

- ☐ Chronic, recurrent or morning cough?
- ☐ Episode of coughing up blood?
- ☐ Increased anxiety or depression?
- ☐ Problems with recurrent fatigue, trouble sleeping or increased irritability?
- ☐ Migraine or recurrent headaches?
- ☐ Swollen or painful knees or ankles?
- ☐ Swollen, stiff or painful joints?
- ☐ Pain in your legs after walking short distances?
- ☐ Foot problems?
- ☐ Back problems?
- ☐ Stomach or intestinal problems, such as recurrent heartburn, ulcers, constipation or diarrhea?
- ☐ Significant vision or hearing problems?
- ☐ Recent change in a wart or a mole?
- ☐ Glaucoma or increased pressure in the eyes?
- ☐ Exposure to loud noises for long periods?
- ☐ An infection such as pneumonia accompanied by a fever?
- ☐ Significant unexplained weight loss?
- ☐ A fever, which can cause dehydration and rapid heart beat?
- ☐ A deep vein thrombosis (blood clot)?
- ☐ A hernia that is causing symptoms?
- ☐ Foot or ankle sores that won't heal?
- ☐ Persistent pain or problems walking after you have fallen?
- ☐ Eye conditions such as bleeding in the retina or detached retina?
- ☐ Cataract or lens transplant?
- ☐ Laser treatment or other eye surgery?

Comments: ______________________________

____

____

____

Men and women answer the following:

List any prescription medications you are now taking: ______________________________

____

____

List any self-prescribed medications, dietary supplements, or vitamins you are now taking: ______________________________

____

____

Past Medical History

Check those questions to which your answer is yes (leave others blank).

- ☐ Heart attack if so, how many years ago? ________
- ☐ Rheumatic Fever
- ☐ Heart murmur
- ☐ Diseases of the arteries
- ☐ Varicose veins
- ☐ Arthritis of legs or arms
- ☐ Diabetes or abnormal blood-sugar tests
- ☐ Phlebitis (inflammation of a vein)
- ☐ Dizziness or fainting spells
- ☐ Epilepsy or seizures
- ☐ Stroke
- ☐ Diphtheria
- ☐ Scarlet Fever
- ☐ Infectious mononucleosis
- ☐ Nervous or emotional problems
- ☐ Anemia
- ☐ Thyroid problems
- ☐ Pneumonia
- ☐ Bronchitis
- ☐ Asthma
- ☐ Abnormal chest X-ray
- ☐ Other lung disease
- ☐ Injuries to back, arms, legs or joint
- ☐ Broken bones
- ☐ Jaundice or gall bladder problems

Comments: ____

____

____

____

Family Medical History

Father:

☐ Alive Current age ____________

My father's general health is:

☐ Excellent ☐ Good ☐ Fair ☐ Poor

Reason for poor health: ____

☐ Deceased ☐ Age at death ________________

Cause of death: ____

Mother:

☐ Alive Current age ____________

My mother's general health is:

☐ Excellent ☐ Good ☐ Fair ☐ Poor

Reason for poor health:____

☐ Deceased ☐ Age at death ________________

Cause of death: ____

Siblings:

Number of brothers _______ Number of sisters _______ Age range ______________________________

Health problems ____

Familial Diseases

Have you or your blood relatives had any of the following (include grandparents, aunts and uncles, but exclude cousins, relatives by marriage and half-relatives)?

Check those to which the answer is yes (leave other blank).

- ☐ Heart attacks under age 50
- ☐ Strokes under age 50
- ☐ High blood pressure
- ☐ Elevated cholesterol
- ☐ Diabetes
- ☐ Asthma or hay fever
- ☐ Congenital heart disease (existing at birth but not hereditary)
- ☐ Heart operations
- ☐ Glaucoma
- ☐ Obesity (20 or more pounds overweight)
- ☐ Leukemia or cancer under age 60

Comments: ____

____

____

____

Other Heart Disease Risk Factors

Smoking

Have you ever smoked cigarettes, cigars or a pipe?

☐ Yes ☐ No

(If no, skip to diet section)

If you did or now smoke cigarettes, how many per day? _______________ Age started ________________

If you did or now smoke cigars, how many per day? __________ Age started

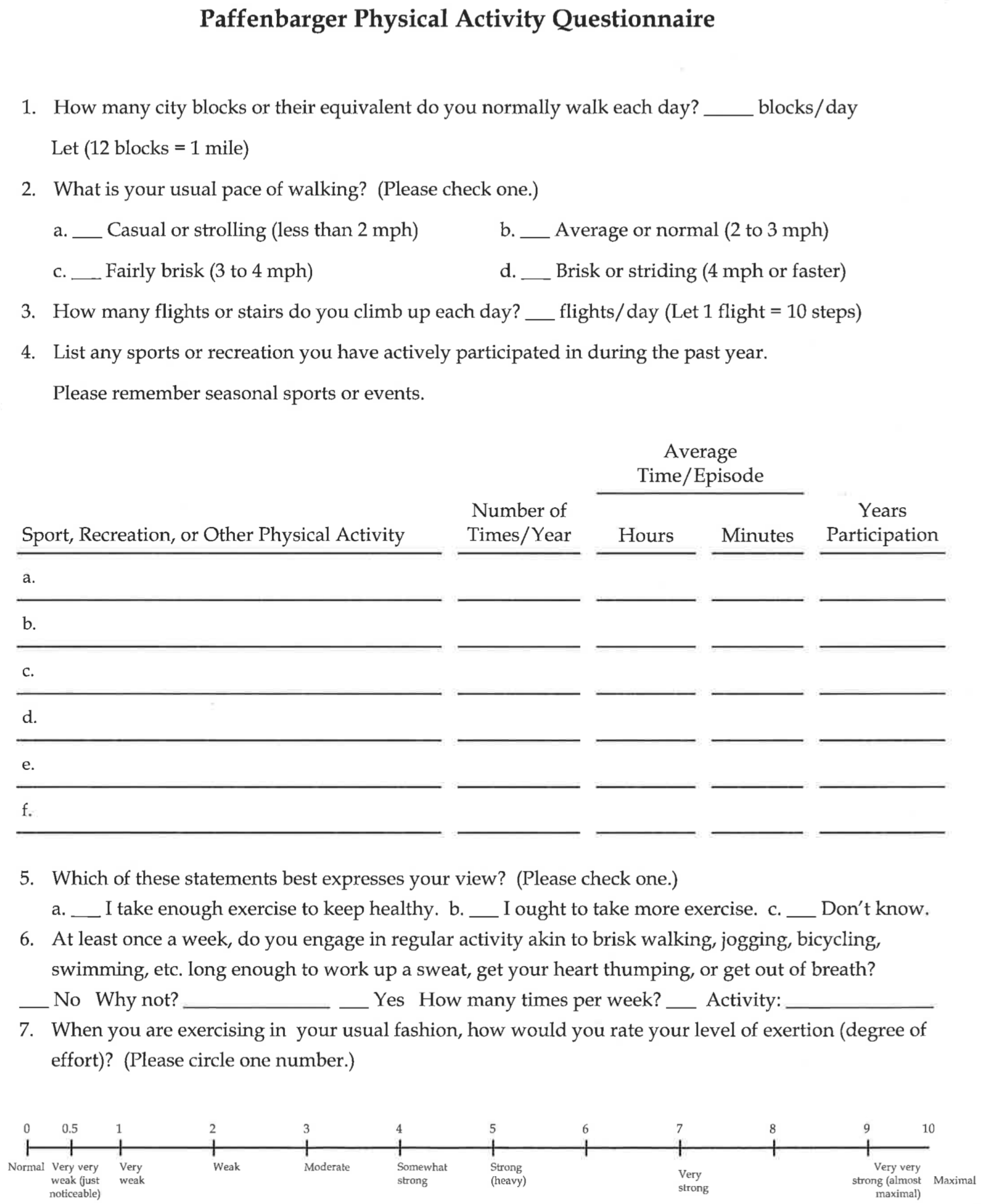
If you did or now smoke a pipe, how many pipefuls a day? _________________ Age started ________________

If you have stopped smoking, when was it? ____

If you now smoke, how long ago did you start? ____

Appendix D

Paffenbarger Physical Activity Questionnaire



Paffenbarger Physical Activity Questionnaire

1. How many city blocks or their equivalent do you normally walk each day? _____ blocks/day
   Let (12 blocks = 1 mile)
2. What is your usual pace of walking? (Please check one.)
   a. ___ Casual or strolling (less than 2 mph)   b. ___ Average or normal (2 to 3 mph)
   c. ___ Fairly brisk (3 to 4 mph)   d. ___ Brisk or striding (4 mph or faster)
3. How many flights or stairs do you climb up each day? ___ flights/day (Let 1 flight = 10 steps)
4. List any sports or recreation you have actively participated in during the past year.
   Please remember seasonal sports or events.

		Average Time/Episode		
Sport, Recreation, or Other Physical Activity	Number of Times/Year	Hours	Minutes	Years Participation
a.				
b.				
c.				
d.				
e.				
f.				

5. Which of these statements best expresses your view? (Please check one.)
   a. ___ I take enough exercise to keep healthy. b. ___ I ought to take more exercise. c. ___ Don't know.
6. At least once a week, do you engage in regular activity akin to brisk walking, jogging, bicycling, swimming, etc. long enough to work up a sweat, get your heart thumping, or get out of breath?
   ___ No Why not? ______________ ___ Yes How many times per week? ___ Activity: ______________
7. When you are exercising in your usual fashion, how would you rate your level of exertion (degree of effort)? (Please circle one number.)

0	Normal
0.5	Very very weak (just noticeable)
1	Very weak
2	Weak
3	Moderate
4	Somewhat strong
5	Strong (heavy)
6	
7	Very strong
8	
9	Very very strong (almost maximal)
10	Maximal

8. On a usual weekday and a weekend day, how much time do you spend on the following activities?

Total for each day should add to 24 hours.

	Usual Weekday Hours/Day	Usual Weekend Day Hours/Day
a. Vigorous activity (digging in the garden, strenuous sports, jogging, aerobic dancing, sustained swimming, brisk walking, heavy carpentry, bicycling on hills, etc.)		
b. Moderate activity (housework, light sports, regular walking, golf, yard work, lawn mowing, painting, repairing, light carpentry, ballroom dancing, bicycling on level ground, etc.)		
c. Light activity (office work, driving car, strolling, personal care, standing with little motion, etc.)		
d. Sitting activity (eating, reading, desk work, watching TV, listening to radio, etc.)		
e. Sleeping or reclining		

Reproduced with permission from Lippincott Williams & Wilkins/Wolters Kluwer Health from Paffenbarger RS Jr, Blair SN, Lee IM, Hyde RT. Measurement of physical activity to assess health effects in free-living populations. Med. Sci. Sports Exerc. 25(1): 60-70, 1993.

Appendix E

Bruce Protocol

Time (min)	**Stage**	**Speed (mph)**	**Grade (%)**
0:00 – 3:00	1	1.7	10
3:00 – 6:00	2	2.5	12
6:00 – 9:00	3	3.4	14
9:00 – 12:00	4	4.2	16
12:00 – 15:00	5	5	18
15:00 – 18:00	6	5.5	20
18:00 – 21:00	7	6	22
0:00 – 3:00	Recovery	2.5	0

Appendix F

Maximal Graded Exercise Testing Recording Document

Circle One: Pre Test 1 Pre Test 2 with Exercise Suit Post Test

Participant ID#:			
Sex:	Age (yr):	Height (cm, in):	Weight (kg, lbs):
Temp: _______ °C	Pressure: mmHg	Humidity:_______ %	Age-predicted Max HR (220-age): ______ bpm

Minute	**Heart Rate**	**RPE**	**Blood Pressure**	**VO2 l/min**	**VO2 $ml\cdot kg^{-1}\cdot min^{-1}$**	**METS**	**RER**	**Tymp Temp**
Rest		X		X	X	X	X	
3:00								
6:00								
9:00			X					
12:00			X					
15:00			X					
20:00			X					
Recovery	■	■	■	■	■	■	■	■
1								
2								
3								
4								
5								

Criteria for stopping the VO_2 max test: Please check which 3 of the 5 occurred:

__Plateau in VO_2 max	__RER ≥ 1.15	__RPE ≥ 18	__HR within 10 bpm of HR_{max}	__ Requested to stop test

Results:

Absolute VO_2 max = ______ **l/min** Relative VO_2 max = ______ **$ml\cdot kg^{-1}\cdot min^{-1}$**

Exercise Time =____________ **minutes, seconds**

Appendix G

Borg Scale for Ratings of Perceived Exertion

ACSM CURRENT COMMENT

Perceived Exertion

Around the world in health clubs on the walls beside treadmills, stationary bikes and step machines, one often sees a scale going from 6-20. This is called an RPE Scale, which stands for “Rate of Perceived Exertion.” It is a psychophysiological scale, meaning it calls on the mind and body to rate one’s perception of effort. Understanding the meaning and use of this chart will benefit the average fitness enthusiast.

The RPE scale measures feelings of effort, strain, discomfort, and/or fatigue experienced during both aerobic and resistance training. One’s perception of physical exertion is a subjective assessment that incorporates information from the internal and external environment of the body. The greater the frequency of these signals, the more intense are the perceptions of physical exertion. In addition, response from muscles and joints helps to scale and calibrate central motor outflow commands. The resulting integration of feedforward-feedback pathways provides fine-tuning of the exertional responses.

Perceived exertion reflects the interaction between the mind and body. That is, this psychological parameter has been linked to many physiological events that occur during physical exercise. These physiological events can be divided into respiratory/metabolic (such as ventilation and oxygen uptake) and peripheral (such as cellular metabolism and energy substrate utilization.) Previous studies have demonstrated that an increase in ventilation, an increase in oxygen uptake, an increase metabolic acidosis or a decrease in muscle carbohydrate stores are associated with more intense perceptions of exertion. The scale is valid in that it generally evidences a linear relation with both heart rate and oxygen uptake during aerobic exercise.

How is perceived exertion measured?
The level of perceived exertion is often measured with a 15 category scale that was developed by the Swedish psychologist Gunnar Borg. The Borg scale is shown below:
6 No exertion at all
7 Extremely light
8
9 Very light
10
11 Light
12
13 Somewhat hard
14
15 Hard (heavy)
16
19 Extremely hard
20 Maximal Exertion
© Gunnar Borg 1985

The Borg scale is simple to understand and very user-friendly. However, to use it effectively, it is necessary to adhere to the standard guidelines in measuring perceived exertion. These guidelines are:

1) It should be clear to either the client, patient, or athlete that perceived exertion is a method to determine the intensity of effort, strain, and/or discomfort that is felt during exercise;

2) The range of sensations must correspond to the scale. For example, number 6 should be made in reference to the feelings during rest, whereas number 20 should refer to the maximal level of exertion;

3) Either the RPE should be made specific to the overall body perception or the perception derived from a certain anatomical region of the body such as chest, arms and/or legs. Typically, individuals interested in monitoring the stress of a workout use RPE ratings.

4) It is important to know that when rating one's perception of exertion there is no right or wrong answer for the rating. However, the individual must clearly understand the meaning of the descriptors, so careful explanation of the scale is necessary before using.

How can ratings of perceived exertion be used?
Due to its reasonably linear relation with oxygen uptake and heart rate, RPE can be used to guide the progression of a graded exercise test. This is accomplished by providing subjective confirmation that end-points of the test have been achieved once the terminal rating is reported or by signaling the relative metabolic stress at a given time during the test. Based upon the fact that RPE's positively correlate to power output over a wide range of intensities, they can also be used to predict aerobic power in a manner analogous to the way that heart rate is employed in submaximal testing.

Ratings of perceived exertion can also be used to prescribe and monitor exercise intensity during a workout. A common approach is to periodically ask a person to rate his or her perceived exertion for a given exercise intensity during a stress test and then match it to an appropriate exercise intensity prescription. Attempting to keep the RPE within a training range similar to heart rate training ranges can be effective. Using this procedure, the target RPE ratings are based upon prior test results, and the person is requested to produce intensity perceived to be similar to the target rating during a workout. The key is close approximation to heart rate in aerobic exercise, where the RPE scale is most often used.

A question is sometimes raised as to whether the intensity produced based on perceptual ratings is actually what it is supposed to be. Several recent studies have attempted to answer this question. These studies have used oxygen uptake as an objective variable and found no difference between the oxygen uptake that was estimated from the prior test results and oxygen uptake that was produced during a subsequent workout. This finding suggests that using a "target RPE" as a guide to regulate exercise intensity is valid.

It is important to note that using the RPE can be especially important in two situations. If heart-rate measurement is difficult for some reason, or if the individual is on medication that alters normal heart rate response to physical stress, RPE can be an excellent tool to regulate and monitor intensity. The RPE scale continues to be a useful tool, offering subjective reflection of physiological responses during physical exercise, and enabling the individual to regulate effort to gain maximum benefit.

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Current Comments are official statements by the American College of
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Appendix H

Leg Strength Protocol and Data Sheet

1. The participant should warm up by completing several submaximal repetitions.
2. Determine the 1-RM (or any multiple RM) within four trials with rest periods of 3-5 minutes between trials.
3. Select an initial weight that is within the subjects perceived capacity (~50%-70% of capacity).
4. Resistance is progressively increased by 2.5 to 20 kg until the subject cannot complete the selected repetition(s); all repetitions should be performed at the same speed of movement and range of motion to instill consistency between trials.
5. The final weight lifted successfully is recorded as the absolute 1-RM or multiple RM

Researcher ________________________________

Circle One: Pre-Test Post-Test

Participant ID#: ____________________________

Sex: __________________ **Age**: ________________

Trial	**Weight**
1	
2	
3	
4	

Max: ________________________________

Appendix I

Exercise Protocol Data Sheet

Test Researcher 1:_________________________

Test Researcher 2:_________________________

Week# (1-6) ______

Exercise Session # (1,2 or 3) _______

Pretest VO_2 Maximum Heart Rate:___________

Participant ID#:			
Sex:	Weight pre exercise (kg):	Weight post exercise (kg)	
Age:	60% MHR:	70% MHR:	60%-70% MHR range:

Stage	**Minute**	**Heart Rate**	**Blood Pressure**	**TympTemp**
Resting	0			
Exercise	5		X	X
Exercise	20			
Exercise	35		X	X
Cool Down	40			

Please indicate if there were any issues with the exercise session in the text box below:

For office use only: Please indicate here any issues with data entry